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Publicizing a Good Rate Structure

By William A. Peters

IN THE beginning of colonization no one would pretend to make a permanent camp where the water supply appeared to be polluted, inadequate and not dependable. If our social, commercial, and industrial life is to grow, and be what we would have it be, the first requisite is a dependable, adequate, and pure water supply.

We have often heard it said that "water should be as free as air. It is a God-given product." These statements are true. Permit me to enumerate a few other "God-given" products which are used by us every day—lumber, cement, lime, gas, coal, gasoline, alcohol, iron, copper, silver, gold, opal, emerald, ruby, diamond, radium, and hundreds of other products. We must admit that all of the products mentioned, in their original status, are "as free as the air we breathe." However, none of them are delivered to us in the form of buildings, fuel, power, heat, automobiles, machinery, jewelery, and thousands of other articles, free of cost. The delivery price, as it should be with water, represents the cost of service applied to the raw material between its native location, and the finished product, f. o. b. point of delivery.

Since the consuming public so often seems to accept as warranted the charges for services by other utilities and at the same time com-

A paper presented on September 18, 1939, at the Rocky Mountain Section Meeting at Fort Collins, Colorado, by William A. Peters, Manager, Jerome Water Company, Jerome, Idaho.

plaints about charges for water service, the author believes it is wise to have ready an explanation for the public. Such an explanation may be set forth in the terms of the hypothetical case given herewith.

The Hypothetical Case of *A*, *B* and *C*

Let us make a study of the water problems of three individuals, *A*, *B* and *C*. Suppose *A*, having a family of two, a cow and a pig, employs an individual or a corporation to carry water from the spring or creek by bucket or other container, for his needs. *B* employs the same person or corporation to pack water from the same point, for a family of ten, five cows, and five pigs. Shall we contend that the two consumers should pay a like amount for the service rendered, by the employed person or corporation? Our unanimous answer is "No." The product is free, but *B* requires five times as much service as *A*.

A and *B* have decided to give up their rural habitation in the hills, and move into the valley at the junction of the two rivers, where the town or city of Junction City, has been platted, and factories and industrial plants are being built. They secure locations adjacent to each other and adjacent to *C*. *C* has already constructed a dwelling and made improvements of various kinds and descriptions. *A* and *B* find that lumber is sold by the foot, cement by the hundred weight, lime by the barrel, gas for fuel by the cubic foot, coal by the ton, gasoline by the gallon, alcohol by the pint, iron and copper by the ton, silver and gold by the ounce, opal, emerald, ruby and diamond by the karat, radium by the milligram, and all other products by some standard measurement, excepting water and water service.

A has disposed of his livestock; desires a comfortable two-story house with full basement. He has taps for sprinkling his lawns, a laundry room in the basement, a kitchen complete in all respects, and bathrooms on first and second floors.

B adds to his livestock; desires a small compact house, including basement and first floor, complete with bath.

C has a comfortable one-story residence located at a considerably higher elevation. The question of water supply for *A*, *B* and *C* is investigated. Upon inquiry *A* finds that the rules provide that he can secure a $\frac{3}{4}$ -inch service for a charge of \$2 per month. *B* can secure $\frac{1}{2}$ -inch service for the charge of \$1.50 per month. *C* finds that he needs a larger connection, because of the elevation of his property, and asks for the installation of a 1-inch service. *C* is informed that

his charge will be \$2.50 per month. All are advised that they are permitted to use all the water needed. Exchanging views among themselves they are unable to understand why the difference, or inequality of the respective service charges. *A* and *B* are informed that their rates are based upon the number of taps or outlets. Permit *A* to call to your attention, that taps and outlets are not consumers of water. They only serve as a convenience. *B* is informed that because of his small service connection, and only a few outlets, he has this low service charge. *C* is advised that his service charge is based upon the size of the service pipe, together with number of outlets. Permit *C* to call to your attention that the size of the service connection, or pipe does not regulate the consumption of water; it serves the consumer, only, as to volume. In this particular case the size of the pipe is designated for the reducing of friction loss.

The community begins to boom. New industries spring up over night. Junction City is laid out upon a large scale. Streets and alleys, parks and fire protection are provided for. *A*, *B* and *C* together with thousands of others are proud of their growing city. Upon investigation they find that the water company, if privately owned, is required to deliver free water to the various city departments, in order to obtain a franchise for the operation of a water system. If municipally owned, no charge is made against the streets and alleys, parks, and fire department, regardless of the fact that from 40 to 60 per cent of the cost of the water system can be charged to fire protection and other municipal uses.

A, B and C Take a Trip

A, *B* and *C* not altogether satisfied with the rate structure submitted for their respective services, decided to make a trip to the city of Three Creeks, an enterprising little city, some 75 miles distant, on the Blank River. The mission was to find out what rules and regulations prevailed as to water rates in the neighboring town of like character. Their investigation brought out the fact that the rate structure in Three Creeks was loosely drawn; no particular attention was given to fire protection, parks, streets and alleys, as far as water service charges were concerned. Charges were approximately the same as those of their home town of Junction City; however, two distinctions in rate structure were noted.

First, approximately 20 per cent of residence consumers were metered, allowing a monthly minimum consumption of 10,000 gal.

Upon inquiry they found that few, if any, of the metered services were using the minimum gallonage, regardless of the installation. Water was carelessly wasted by most of the consumers contacted.

Second, they found a graduated charge made for connections to transmission lines as follows: \$15.00 for a $\frac{1}{2}$ -inch connection, \$17.50 for a $\frac{3}{4}$ -inch connection, \$20.00 for 1-inch connection, and like charges for larger connections which were appurtenant to hotels, apartment houses, industrial plants, etc. Upon inquiry they found that such charges were made for materials and labor required to bring water service lines from the transmission line or main to the consumer's property line. They asked themselves the question: "Why should a consumer of water be charged for labor and for materials which were, and are at all times, the property of the city, or water corporation?" A consumer's rights begin only after the service pipe enters his property. Taking it by and large, *A*, *B* and *C* concluded that the rate structure in Junction City was about in line with their neighboring town, and ordered service installed.

Town Changes; Rates the Same

It is now 25 years later. *A* is a member of the City Council. *B* is a member of the Chamber of Commerce, and has been appointed by said organization to inquire into water rates and water supply. *C* is a member of a committee appointed by the Tax Payers League, to investigate rising taxes and to study the reasons why the city water department is unable to meet its regular operating expenses, to say nothing of depreciation and a reasonable return on investment.

Junction City has grown to be a city of considerable importance, industrially and commercially; thousands of retired farmers and business men from the surrounding country have moved into town, to lead what might be termed a quiet life. Water supply, which a few years ago seemed inexhaustible, has diminished; adequate supply is a problem during the peak load of the summer months. It is necessary to rotate water for sprinkling purposes from one side of the city to the other during July and August. Many of the residents and commercial consumers, at times, are unable to draw water above the first floor; thus, the water situation is the problem of the moment.

A, *B* and *C* as representatives of the city water conservation committee and Tax Payers League have decided to make another trip to Three Creeks to investigate city water conditions of their neighbor. Three Creeks has made a rapid growth, but water shortage has

developed during the peak season; approximately 75 per cent of the services have been metered; a reduction of minimum gallonage to each residence consumer was made from 10,000 gal. to 5,000 gal.; public parks were suffering for the want of water; streets and alleys were unkept because of the lack of water. Fire hydrants were being used indiscriminately by individuals, contractors and others, whenever the occasion demanded, with no regular charges for the water taken from the hydrants. During a fire, the week last past, the hydrants failed to function, and water supply and pressure were negligible. Three Creeks like Junction City, had over-taxed the source of its water supply, through waste caused by faulty rate structure, and was now forced to look for additional source of supply, at heavy expense.

After leaving Three Creeks, *A*, *B* and *C* visited the city of Twin Springs, in the northwestern part of the state. Twin Springs was extensively platted approximately twenty years ago and is now a beautiful, bustling little city, located in a farming and industrial region. Upon their arrival at Twin Springs, *A*, *B* and *C* informed Mayor *X* and the Water Superintendent *Z* of their mission. A careful and considerate survey of the water rate structure, rules and regulations was made with the following findings:

The water corporation provided service lines, required by the consumer, regardless of the size, to the consumers property line. All services of every kind and description including those for sprinkling of city parks, and other public grounds, were metered. All water used by the street and alley department for sprinkling purposes was accounted for, and charged against said department, in favor of the water corporation. A monthly rate per fire hydrant was charged to the fire department for each and every fire hydrant installation. No person, firm or corporation, excepting the fire department, was permitted to take water from fire hydrants, without the written consent of the water department. The water corporation was charged with keeping all of the hydrants in first class condition. Residential rates were based upon a monthly minimum consumption of 2,500 gal.; the charge for such minimum was adequate, just and equitable. Commercial and industrial services were granted generous minimum consumptions, depending upon the average monthly needs; charges for such minimums were compatible with sound business. A nominal charge was made against residential consumers for water used upon lawns and gardens; such additional use was based upon

the consumption as shown by meter over and above the average use for domestic and culinary uses. An intensive campaign was waged at all times, requesting all consumers to eliminate waste of water by checking water fixtures of every kind and description. The water corporation rendered every assistance possible toward the elimination of waste, to any and all consumers, without charge. *A*, *B* and *C* were told that waste of water by the various city departments was and is a definite economic loss; that the water rate structures should be presented and explained to the consuming public, from the standpoint of service and not price; and that the water corporation should advertise to the consumer and general public a 100 per cent service, a first quality product, for an adequate, just and equitable charge.

With the information acquired, *A*, *B* and *C* returned home to Junction City. Entering the town on No. 30, *A* directed *B* and *C*'s attention to Lincoln Park, dotted with shrubbery and trees, with the remark, "It is surprising how well our parks and public grounds are kept up, considering the depleted water supply." *B* in turn remarked that the street and alley department is to be complimented for the cleanliness of the city, considering the interrupted water supply. Upon entering the business district they noted a conflagration, just being brought under control by the valiant fire department, which was made possible, by the superintendent of the water department and his co-workers, in diverting the city's entire supply of water through the mains located at the place of the fire.

A, *B* and *C* asked themselves the following: What would our parks and public grounds be without an ample supply of water? Would we be proud of our streets and alleys without sufficient water to keep them clean? Would not destruction of life and conflagration of property go unchecked, excepting for the services of the water department, and a dependable and adequate supply of water?

"Lest we forget," *A*, *B*, *C* and every citizen from coast to coast, from border to border, should raise their voices, not in the near or distant future, but now, in appreciation and understanding of the work of the laborer, the expert, the technician, and the executives of our respective water systems.

A, *B* and *C* in their report to the City Council of Junction City recommended that the rate structure of Twin Springs be adopted with the necessary changes to meet local conditions.

The report of *A*, *B* and *C* represents, in the opinion of the author, a "streamline" rate structure for up-to-date water corporations and city departments.



Economic Evaluation of Tuberculation in Pipe Lines

By Louis J. Alexander

TUBERCULATION and the losses caused by it are perhaps the least understood factors affecting the costs of water works operation. Tuberculation and its relative, corrosion, have been the subject of vast treatises; but few attempts to evaluate the losses caused by tuberculation have been made. If the damages caused by tuberculation are understood, an attempt can be made to determine and evaluate these losses.

Any metal used in water works practice, when subjected to the action of the elements, will revert to mineral forms found in nature. Corrosion and tuberculation are terms applied to the processes of the reversion of metallic forms to natural compounds. Metals subjected to corrosive action disintegrate and enter the water as soluble salts, but in the action of tuberculation the metal increases in volume as an oxide, sulfate, or some other insoluble salt. In either case the original strength of the metal is reduced, and any reduction in original strength is costly. The rate of disintegration determines the "life" of a material. This is "depreciation." Corrosion and tuberculation cause depreciation. In addition to causing depreciation, corrosion and tuberculation cause increased operating costs. It has always been difficult to determine proper charges for depreciation. Further, the cause of increased operating costs often is not understood, and not being understood cannot be properly assigned.

It is the purpose of this paper to indicate the methods for making computations to arrive at charges which reflect actual rather than hypothetical conditions. The subject has been divided into four

A paper presented as part of a symposium on October 26, 1939, at the California Section Meeting at San Francisco, by Louis J. Alexander, Assistant Engineer, Southern California Water Company, Los Angeles.

parts, entitled "Pipe Friction," "Pumping Costs," "Depreciation," and "Pipe Cleaning." In each part there is a general statement of the problem, also examples showing typical methods for determining the economic evaluation of tuberculation in pipe.

Pipe Friction

Pipe friction is the force of retardation which causes resistance to the flow of water in pipe. In studying pipe friction it must first be understood that the flow of water in pipe is obtained from the formula $Q = AV$ where Q is the quantity, A the area of the internal cross-section of the pipe, and V the velocity of flow. The term V , representing velocity of flow, has been the subject of vast treatises ever since Chezy in 1775 first proposed his famous formula:

$$V = C R^{0.5} S^{0.5}$$

Since Chezy proposed this formula, the coefficient C has been found to vary, not only with the character of the pipe wall, but also with the slope, and with the hydraulic radius (area of water cross-section divided by the wetted perimeter). Each subsequent investigator has tried to develop a formula so stated that the influences of slope and hydraulic radius could remain constant for any reach of pipe. Then C , or the flow coefficient, might indicate the character of the interior surface of the pipe wall and indicate an influence caused by reduction of the area of the water cross-section.

It was Allen Hazen and Gardner S. Williams who, after repeated experiments and measurements of actual conditions of flow of water in pipe, proposed a formula which is used almost universally, namely:

$$V = C R^{0.63} S^{0.54} 0.001^{-0.4}$$

in which

V = Velocity of flow in feet per second.

C = Factor depending upon the roughness of the internal pipe wall and spoken of in this paper as the flow coefficient.

R = Hydraulic radius, the area of water cross-section divided by wetted perimeter ($A \div P$) expressed in square feet.

S = Slope of hydraulic gradient expressed in feet per 1,000 feet.

The exponents of R and S compensate for the influences of hydraulic radius and slope. The added factor $0.001^{-0.4}$ permits S to be expressed as slope in feet per 1,000 feet. C , the flow coefficient, then indicates only those influences causing a retardation of flow.

The following formula, derived by Kutter, is used for computing flow in open channels, or conduits flowing partially full.

$$V = \left[\frac{\frac{1.811}{n} + 41.66 + \frac{0.00281}{s}}{1 + \left(41.66 + \frac{0.00281}{s} \right) \frac{n}{\sqrt{R}}} \right] \sqrt{Rs}$$

in which

V = Velocity of flow in feet per second.

n = Factor depending upon roughness of internal pipe wall.

R = Hydraulic radius.

s = Slope of hydraulic gradient expressed in feet per foot.

The value of n has been found to be quite constant for flow in open conduits.

Fred C. Scobey of the United States Department of Agriculture (Bulletin No. 194 of the U. S. Department of Agriculture) developed excellent diagrams for the solution of problems involving Kutter's formula. In pipe flowing full, the value of n often has considerable variation. The formula was used for many years, however, for all types of conduit, whether open or closed, whether flowing full or partially full. The complicated relationships and influences of slope and hydraulic radius are well illustrated in this formula. The flow coefficient n in this formula is of a different numerical value from that of C in the Hazen-Williams formula, but the relationship is indicated on Fig. 1.

Scobey has done more than any other investigator in research on flow of water in all types and classes of conduit. One of the U. S. Department of Agriculture Bulletins ("The Flow of Water in Steel and Analogous Pipes," Technical Bulletin No. 150) is of special interest to the water works man. In this publication Scobey proposed the formula:

$$V = \frac{H^{0.53} D^{0.58}}{K^{0.53}}$$

in which,

V = Velocity in feet per second.

H = Head of elevation lost in overcoming internal resistance in feet per 1,000.

D = Mean inside diameter of pipe in feet.

K = Retardation coefficient.

Due to the form of statement of the formula the flow coefficient K has a numerical value different from either C or n , but Fig. 2 illustrates the relationship between C and K .

The mathematical relationships between the formula of Hazen and Williams and the other two formulae do not plot, as indicated by the curves shown on Figs. 1 and 2. The data to plot the curves shown on these plates were taken from the above mentioned Bulletin No. 150. The curves are shown for comparison of the coefficients used in these formulae and are of interest because by their use a mass of interrelated data may be correlated and used approximately with the Hazen-Williams formula. By the use of Figs. 1 and 2, design com-

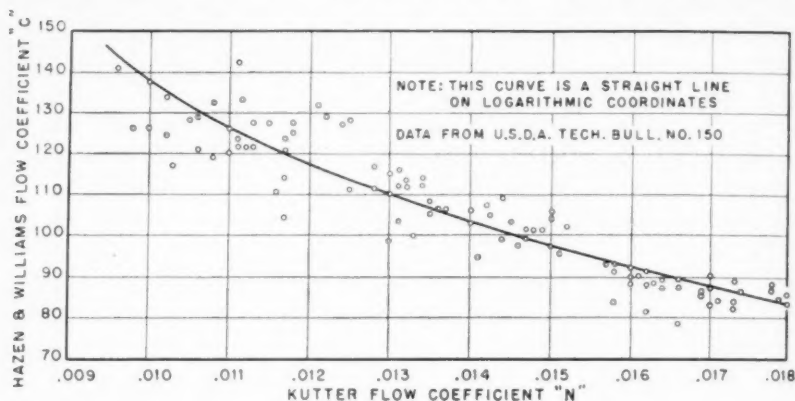


FIG. 1. Flow Coefficients, the Hazen-Williams C and Kutter's n

putations based on these formulae may be related to computations using the Hazen-Williams coefficient C .

Solution of any of the various formulae for velocity of flow is difficult. This is because of the fractional exponents involved. Following the development of a slide rule to solve the Hazen-Williams formula, that formula has become one universally used. There has been an excellent set of tables published (*Hydraulic Tables*, John Wiley and Sons, Inc., New York) which was prepared using this slide rule (furnished by Ledder and Probst, Inc., Boston).

The diagram, Fig. 3, has been prepared from the values shown in that book of tables. Its use simplifies any computation involving the use of the Hazen-Williams formula. It goes one step farther and completes the solution for quantity of flow. The lines marked "diameter of the pipe" are in reality the lines of area of water cross-

section. The diagram includes various flow coefficient lines to enable the designer or investigator to solve quickly for C as well as quantity, slope, pipe sizes, or velocity. Thus with any three known factors, the fourth and fifth may be found.

By the use of this diagram, results may be obtained directly for any of the following conditions, without detailed computations.

(1) If a certain quantity of flow (gallons per minute) is required and the slope is known (in feet per 1,000), it is possible to determine the C that must be maintained for any size of pipe.

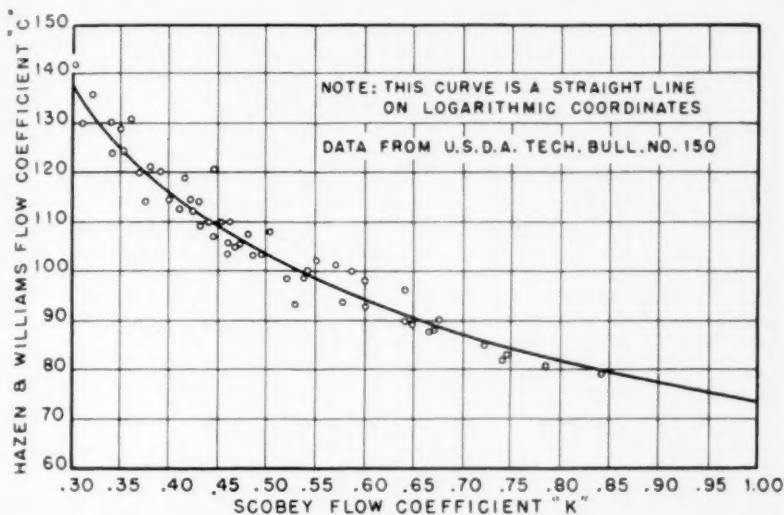


FIG. 2. Flow Coefficients, the Hazen-Williams C and Fred C. Scobey's K

(2) If a desired quantity of flow is to be maintained, the diagram will indicate, for any size of pipe, how much the head or slope must be increased to overcome the frictional resistance caused by tuberculation in the pipe line (reflected by a reduction in C).

(3) If the pressure head remains constant for any size of pipe, the diagram will show how much the carrying capacity of the pipe has been reduced because of increased frictional resistance (reduction in C).

(4) If the flow and pressure head are determined by measurement for any given size pipe, the diagram will show the value of the coefficient C , which, when compared with the coefficient for new pipe will indicate the extent of tuberculation.

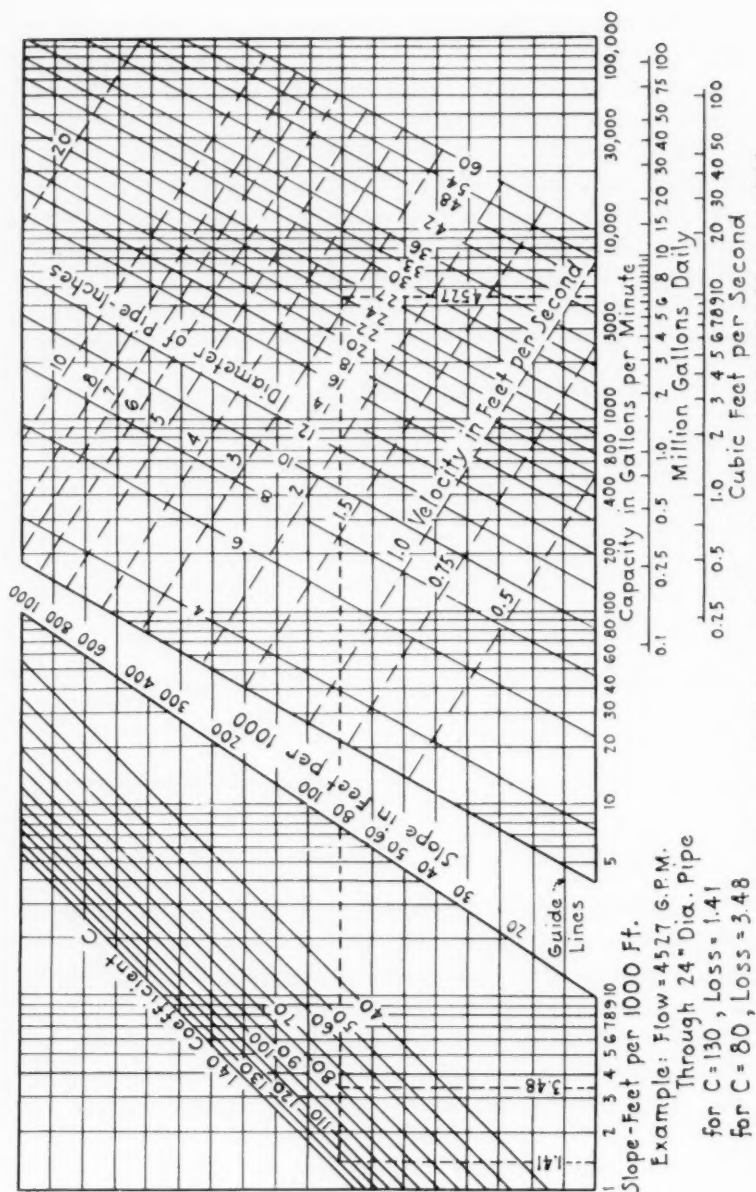


FIG. 3. Diagram for computations using the Hazen-Williams formula for flow of water in pipe

Diagrammatic Solutions Involving Hazen-Williams Formula

In the typical examples described below, no consideration has been given to increased flow requirements caused by changes in population or by other conditions.

Example 1. A transmission line 24 in. in diameter and one mile long was designed to carry 4,527 g.p.m. (gallons per minute), or 6.5 m.g.d. (million gallons daily). To impel that quantity of water through the pipe line, pumps were designed and purchased to overcome the static lift and 7.44 ft. of frictional resistance. The frictional resistance was based on a C of 130, which was the coefficient selected for the type of pipe line to be constructed.

To check the original design, enter the diagram at 4,527 g.p.m., follow up vertically to the 24-inch diameter pipe, then by the guide lines horizontally to $C = 130$, then down vertically to 1.41 ft. per 1,000 on the slope scale. For one mile of pipe, multiply 1.41 by 5.28 to obtain the total friction head to be overcome, in this case 7.44 ft.

Suppose that the pipe line has been in service for some years and that tuberculation has been increasing continuously, as it invariably does. As a consequence, the field measurements indicate that the flow coefficient has been reduced to $C = 80$.

Follow the same procedure as outlined above, but stop at $C = 80$. Then read vertically down to 3.48 ft. per 1,000. Multiply this by 5.28, and the total friction head is 18.37 ft. The added resistance due to tuberculation is then 18.37 minus 7.44, or 10.93 ft. To pump 6.5 m.g.d., as originally specified, through this additional frictional resistance of 10.93 ft., will cost \$1,165 per year per mile for energy only, (when power is assumed to cost one cent per kw.hr. and the overall efficiency of the pumps and motors is assumed to be 70 per cent). Such a cost is directly reflected in the year's operating expense.

Example 2. Suppose that this same 24-inch transmission line which was designed to carry 4,527 g.p.m. originates at a reservoir of fixed elevation. Thus, there is no opportunity to increase the pumping head to overcome the frictional resistance caused by tuberculation. A total frictional resistance of 7.44 ft. was provided for in the design, but after some years the ravages of tuberculation have reduced the coefficient C to 80.

Enter the diagram at the slope of 1.41. Follow vertically to $C = 80$; then follow the guide lines horizontally to the 24-inch diameter pipe line; and read vertically down to 2,650 g.p.m. Then 2,650

divided by 4,527 shows that the line is only 58.7 per cent efficient, as compared with the line when new. This 24-inch line with the coefficient C reduced to 80 is no better than a 20-inch pipe line.

If the territory served requires that 6.5 m.g.d., or 4,527 g.p.m. be delivered, either the line must be cleaned or a new 18-inch line must be installed to carry the difference of 1,877 g.p.m. ($4,527 - 2,650 = 1,877$).

The cost of cleaning, or the installation of the 18-inch pipe line, must be provided for, either as an operating expense or taken from depreciation reserve account. In either case there is a direct reflection of the cost of tuberculation.

Example 3. Field measurements of quantity of flow and slope may be made. From these, and the use of the diagram, it is possible to determine the coefficient C for the particular reach of pipe. If such measurements are made periodically it is possible, by the use of the diagram, to determine the rate of tuberculation.

Suppose, for example, that in January, 1930, measurements of flow indicated that the pipe was carrying 4,527 g.p.m. (Example 1) and that the slope of the hydraulic gradient was 7.44 for the mile, then for $7.44 \div 5.28$ the slope in feet per 1,000 was 1.41. The diagram then indicates a value of $C = 130$. Now, in October, 1939, similar measurements indicated (Example 2) a flow of 2,650 g.p.m. with the same head loss or slope of the hydraulic gradient. The diagram for the same 24-inch pipe indicates a C of 80. Reduction of C from 130 to 80 in the approximate 10-year period would indicate that tuberculation was proceeding with great rapidity.

The reduction in efficiency of this line to 58.7 per cent (Example 2) in ten years indicates a yearly loss of 4.13 per cent $\left(\frac{100 - 58.7}{10}\right)$.

Such a loss must be compensated for. This may be done by allocating an amount larger than usual to depreciation reserve to pay for paralleling the line with an 18-inch pipe (Example 2); or, should pipe cleaning be the alternative, the cost would be reflected in an increased operating expense.

Pumping Costs

Pumping costs are reflected in the yearly power bills. To understand changes which are reflected in greater yearly operating expenses, an understanding of the principles of operation of the centrifugal pump is necessary.

The centrifugal pump is essentially a machine for generating dynamic pressure. As such it is a machine that produces flow, not because the water is pushed bodily along as it is by a piston pump, but the pressure produced modifies the hydraulic gradient in a way that makes flow possible because of the immediate elevation of the hydraulic gradient. The centrifugal pump is the reverse of a reaction turbine, and when one understands the phenomenon of falling water, the action (in reverse) of a centrifugal pump becomes clear. When water falls through a given height, its velocity, when it strikes the ground, is expressed as $V = \sqrt{2gh}$. In requiring water to be lifted up through any given height, a velocity equal to that of falling water (falling through the same distance) must be attained. The action of the impeller of the centrifugal pump is to impart that velocity to the water, and this is accomplished by the peripheral speed of the rotating impeller. As the water enters the eye or center of the impeller, and is guided by means of the internal veins, it is whirled and gathers centrifugal force until it is discharged tangentially to the direction of rotation at a velocity equal to that of falling water. By means of the pump case and the change in direction of the water, the velocity (velocity head) is converted to hydraulic pressure. In other words the velocity head is converted into sufficient pressure head to overcome the change in hydraulic gradient. Sufficient change in hydraulic gradient must be imparted to the water to overcome the static lift plus enough more to overcome frictional resistance. As the frictional resistance increases, more pressure head must be imparted, and, in turn, more velocity head. But due to the inherent characteristics of a centrifugal pump, there is a definite relationship between the amount of water that may be forced through the impeller, and the velocity head produced; or, the more water, the less the velocity head, and vice versa. Thus at some point of operation the maximum velocity head (and in turn pressure head) is reached, and at that time there is little or no water being passed by the pump. At the other end of the curve, when all possible space in the impeller is occupied by the flow of water, it takes all of the energy imparted to the impeller merely to pass the water. Then there is little or no velocity head imparted to the water.

Thus if the relationship between pressure head (velocity head having been converted in the pump case) and volume is plotted, we obtain the "head capacity curve" of the centrifugal pump. Such a curve has been plotted on Fig. 4.

Each pump has some point at which it will accomplish the most work with the least applied force. That point is the point of maximum efficiency. With variation either way from this maximum, the amount of work accomplished in relation to applied energy, de-

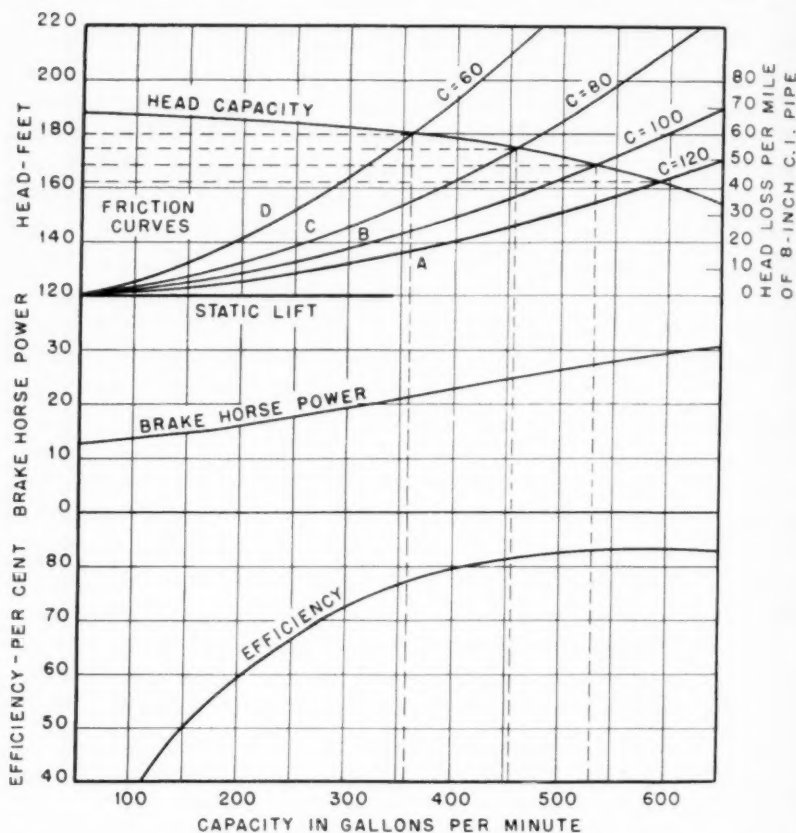


FIG. 4. Centrifugal Pump Characteristics; relationship of changes in operating characteristics caused by changes in flow coefficients

creases. This relationship is shown on Fig. 4 as the "Efficiency Curve."

The theoretical amount of work required to raise water through any given elevation is expressed as $\frac{\text{g.p.m.} \times \text{Head}}{3960} = \text{T.H.P.}$ The result of this computation divided by the efficiency of the pump gives the amount of power which must be applied to the shaft of the pump. The result of a series of these relationships, when plotted, is the

"brake horse power curve" of Fig. 4. These three curves show the operating characteristics of the pump.

All centrifugal pumps are designed to meet certain specific needs, or to operate at maximum efficiency under certain conditions. It follows that when the conditions of operation vary from the optimum, the operating characteristics change.

When any characteristic changes, certain things happen to the operation of the pump.

(1) As the head rises, the capacity decreases, and often the power input decreases.

(2) As the head decreases, the capacity increases, and often the power input increases.

In both cases the efficiency *decreases*.

When there is tuberculation in the pipe line, the head increases due to a change in C , i.e. a reduction in net area of the pipe and an increase in roughness or frictional resistance of the pipe wall takes place.

Curves A , B , C , D , Fig. 4, are "Friction Curves" for one mile of 8-inch pipe when C has been progressively reduced by tuberculation from 120 to 100, 80 and 60. (Data to plot these curves were computed by use of Fig. 3.) These friction curves cross the head capacity curve of the pump at points of increasing head and decreasing capacity. Projecting these points downward (by the dotted lines), a decreasing horsepower is indicated, but more important, decreasing efficiencies are indicated.

Computing Pumping Cost Due to Increased Friction

Conditions of flow, and pipe size were assumed in the following example to best illustrate the problem graphically.

Example 4. Suppose that a pump was designed to pump 600 g.p.m. through one mile of 8-inch pipe through 120 ft. of static lift and 42 ft. of friction head, a total of 162 ft. This 8-inch pipe, when new, had a frictional coefficient of $C = 120$. This pump would in 10 hr. force 360,000 gal. through this one mile of 8-inch pipe and would require 29 b.h.p. delivered to the shaft of the pump. If the motor were 90 per cent efficient, this would amount to a total input of 240 kw.hr. each day. At \$0.01 per kw.hr. this would be a daily cost of \$2.40.

After some years of operation, this pipe line becomes tuberculated until the coefficient is reduced to $C = 60$, at which time the pump is found to be operating as follows: head, 180 ft.; capacity, 355 g.p.m.; efficiency, 77 per cent; brake h.p., 21; all of which indicates that to

pump 360,000 gal. per day would require 16.85 hr. of pumping which, with the same 90 per cent motor and same \$0.01 kw.hr., would cost \$2.93 per day. Translated into yearly cost, this increase of \$0.53 per day amounts to \$193.35. This is an operating cost of 22 per cent. Whether the plant is large or small such an increase in percentage of operating cost is prohibitive. These data are tabulated in Table 1.

Had this unit been designed to operate 24 hr. a day in place of 10 hr., the required quantity of water could not be delivered to the consumer. Then the operator would be faced with the purchase of a

TABLE 1
Showing Flow and Operating Characteristics of a Centrifugal Pump

ITEMS	CONDITION OF ORIGINAL DESIGN OPERATION	CONDITIONS OBTAINED FROM MEASUREMENT TODAY
Pump capacity in g.p.m.....	600	355
Static lift in ft.....	120	120
Flow coefficient.....	120	60
Total frictional resistance in ft.....	42	60
Total dynamic lift in ft.....	162	180
Total daily pumpage in gal.....	360,000	360,000
Hours to pump above quantity.....	10.0	16.85
Pump efficiency, per cent.....	83	77
Brake horse power input.....	29	21
Total kw. hr. input, 90 per cent motor.....	240	293
Daily cost @ \$0.01 per kw. hr.....	\$2.40	\$2.93
Daily increase in power cost.....	—	\$0.53
Yearly increase in power cost.....	—	\$193.35
Per cent increase in operating cost.....	—	22

bigger and better pump, or an additional pipe line. It is again out of place in this paper to attempt to estimate the cost of pump replacement or cost of additional pipe line, but some means must be provided in the yearly charges to take care of this increased operating cost.

Depreciation

One of the most serious problems confronting the water works man is to determine the amount to be set aside from gross revenue and applied to the depreciation account. The most common method is to use the so-called "straight line method" in which an arbitrary age

or the probable life of the pipe is set up, based on the general average for the material from which the pipe is made. The life of cast iron is often taken to be 100 years, but by some, 50 years. Similarly, other metals are said to have a certain life.

It has been found that the life of any metal varies according to so many conditions that to obtain even a fair judgment of the rate of depreciation some other method should be used. Some of these conditions governing the probable life are: quality of water, its corrosivity, the rate of tuberculation, the rate of precipitation of semi-soluble salts (calcium carbonate, etc.), bacteriological content of water and the resultant amounts of slimes that may accumulate on the interior pipe wall, and soil conditions. (The latter was not taken to be within the scope of this paper.) Appraisals of "life" have been made by cutting samples from the pipe which are then cleaned, weighed, and otherwise judged to determine the loss of metal. The remaining weight of metal compared with the weight of new pipe indicates the remaining percentage value. This is the "condition per cent." The percentage of loss as related to age will indicate the rate of loss or the rate of depreciation. Depreciation based on such an analysis is said to be computed by the "condition per cent theory."

It is often difficult to determine the true condition per cent by cutting into a pipe system in a few locations. Further, such a method is at best very "spotty" and considerable "good judgment" must be used. Nevertheless, it will show greater accuracy than can be obtained by assuming some hypothetical "probable life." Cutting samples of pipe for measurement will fail to show one important factor of depreciation, namely, the relative carrying capacity of the pipe. By methods suggested in Example 3, for taking field measurements to determine periodically the change in the flow coefficient, a better measure of the "condition per cent" may be arrived at. The following hypothetical case was chosen to illustrate the method of computation and further illustrate the point.

Example 5. A mile of 24-inch cast-iron pipe (Example 3) was installed. Measurements of flow in the line immediately after installation (flow 4,527 g.p.m., head loss 1.41 ft. per 1,000) indicated that the flow coefficient was 130. Periodically, similar measurements were made, the progressive percentage reduction of flow due to decreasing values of C was plotted on a curve. Figure 5 shows the result by curve *A*. Curve *B* of Fig. 5 indicates the progressive reduc-

tion of percentage of capacity on a "straight line basis" on the assumption that the capacity would be 50 per cent of that of new pipe in 50 years.

It may be seen that if a sum, sufficient to replace this line at the end of 50 years, is allocated to that line, the operator will not have provided for the proper amount of depreciation. (No consideration is here given to the necessity of replacement due to changes in flow requirements.) Assuming that the mile of 24-inch line cost \$46,000, on the basis of a "straight line depreciation," the amount that should be set aside on a 5 per cent annuity basis is \$200.80 per year. At the end of twenty years, the flow capacity has been reduced by tubereu-

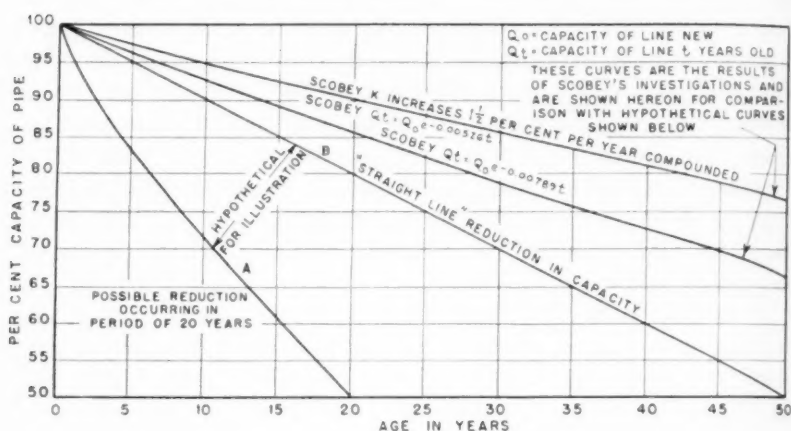


FIG. 5. Rates of Loss in Pipe Capacity

lation to a point where the line has lost capacity equivalent to that lost under ordinary circumstances in 50 years. At the end of the 20 years, the accumulated annuity for depreciation would amount to \$6,716. Based on the same unit costs, this would not be sufficient to replace the 24-inch line, and would not be enough to parallel the 24-inch line with the 18-inch (Example 2) required to obtain the same carrying capacity.

It may be seen that by the use of occasional field measurements and the ability to determine C easily from the flow chart (Fig. 3) a better index of the amount that should be set aside for depreciation reserve may be determined.

Pipe Cleaning

The other papers of this symposium have to do with the ravages caused by corrosion and tuberculation and also consider methods of prevention. In this paper it has been shown that tuberculation in pipe increases operating costs and that additional amounts should be set aside for depreciation. There are many thousands of miles of pipe now in place which are causing losses herein described. These losses could be reduced if the pipes were cleaned by mechanical methods.

Many claims have been made to show that flow coefficients better than the "original" have been obtained by cleaning; or, that the "original" coefficients have been restored. Assuming that these claims are true, pipe cleaning would be economically feasible.

It is not here advocated that pipe cleaning is the panacea for these losses. It is merely a "helper" in the solution of the problem as a whole. The final answer in all cases is the proper treatment of the water to be carried by these lines. But such treatment, while effective on new lines, does not correct the existing ills of many thousands of miles of pipe now in place. The proper answer is two-fold. Clean the existing pipe and restore it as nearly as possible to its original flow characteristics. Then treat the water so that conditions are not favorable to recurring corrosion or tuberculation. However, to determine the economic feasibility of cleaning the pipe, or the installation of proper treatment works, all conditions must be studied for each problem.

This paper is of necessity general in its scope, because each individual problem must be evaluated. For purposes of simplicity, no attempt has been made to study a distribution network, but instead to confine the examples to single reaches of pipe.

It is hoped that the suggestions and methods contained herein will be of assistance to operators in solving particular problems.

Discussion by Clinton Inglee.* Mr. Alexander has brought out under the section of his paper devoted to "Depreciation" the fact that loss of capacity as well as structural life must be taken into consideration and he has set up a hypothetical case under Example 5 showing that the reserve at the end of twenty years as determined

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by the straight line method would not be sufficient either to replace the 24-inch line or to lay a parallel 18-inch to provide the required capacity.

In a paper previously published (Jour. A.W.W.A., 30: 773 (1938)) this discussor gave two tables—the one on page 774 showing carefully determined before and after cleaning coefficients for various diameters of pipe in widely distributed localities. These and many other tests show that water mains can be mechanically cleaned and capacities restored to those of new pipes.

The table on page 782 of the same paper gives an average cost of cleaning based upon wide experience.

By cleaning at such times as may be necessary to give the required capacity, the useful life of water mains is only limited by their structural life. But in addition to the depreciation costs as determined by the physical life there must be added the cost of cleaning so that at any given period a reserve will have been set up to cover the cost of bringing the line back to capacity. In his Example 5 Mr. Alexander assumes that "C" will have dropped to 50 at the end of twenty years. Experience has shown that after the first cleaning the drop in "C" value is more rapid than when the pipe was newly laid. The cost of cleaning the mile of 24-inch line would be about \$1,500. On a 5 per cent annuity basis and assuming that it might be necessary to clean the line as often as every five years after the first cleaning, the annual deposit to reserves would be \$45.36 for the first twenty years and \$271.47 annually thereafter to keep up the line capacity.

No one as yet knows what the average life of cast-iron pipe may be but certainly under fairly neutral soil conditions one hundred years would seem a conservative estimate. On the 5 per cent basis, \$17.62 annually placed in the reserve would amount to \$46,000 in 100 years, so that \$52.98 annually during the first twenty years and \$289.09 thereafter would take care of capacity as well as physical depreciation.

With the research work now being done by many of our water works chemists and engineers we may well expect that preventive measures against corrosion and the resulting coefficient drop will be successful. Already in some instances there have been very satisfactory results; in others the solution is yet to be found.

The economics of each individual case must determine whether the treatment alone, cleaning plus treatment, or cleaning alone best meets the requirements.



Corrosion and Tuberculation

By H. A. Knudsen

IT IS the purpose of this paper to present concisely the nature and probable causes of internal corrosion. In order to cover the subject completely a search has been made of papers and other published works on the subject and as a consequence this paper is a composite of the contributions of others combined with independent observations.

Investigations of internal corrosion have not kept pace with efforts to analyze and determine the causes of external or soil corrosion of water conduits and containers. This is probably due to the fact that internal corrosion is usually much the less severe of the two and consequently does not present the same hazard or problem.

Fundamentally internal and external corrosion take place by the same process, namely electrolysis, the principal difference being that rarely if ever are stray currents involved in internal corrosive action. Galvanic action is the source of trouble.

Galvanic action in its simplest form results from two dissimilar electrodes, in contact, immersed in an electrolyte. Water with minerals or other substances in solution is by far the most common electrolyte, and of course the only one of concern in this paper.

The most elementary problem in internal corrosion of metallic water conductors or vessels is that due to dissimilar metals used in construction. Brass or copper and iron are frequently used in combination. Zinc galvanizing adjacent to iron not similarly protected is frequently used. In both instances the iron corrodes. Red lead paint is often used as a shop coat on the inside of large steel valves or specials and because the red lead coated portion remains in perfect condition while adjacent uncoated portions of the steel become badly

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pitted it is assumed that the paint has protected the metal in a highly corrosive environment. The facts of the case usually are that the water is not necessarily corrosive but that red lead is cathodic to steel and that the corrosion of adjacent bare metal is caused by the presence of the paint and the total corrosion would not have been as great had the red lead not been present.

Other variations of dissimilar metals are differences in stress of the same metal. Stressed portions are anodic to the unstressed or lightly stressed portions. Rivet heads corrode for this reason and the fact that they are usually much harder than surrounding plate.

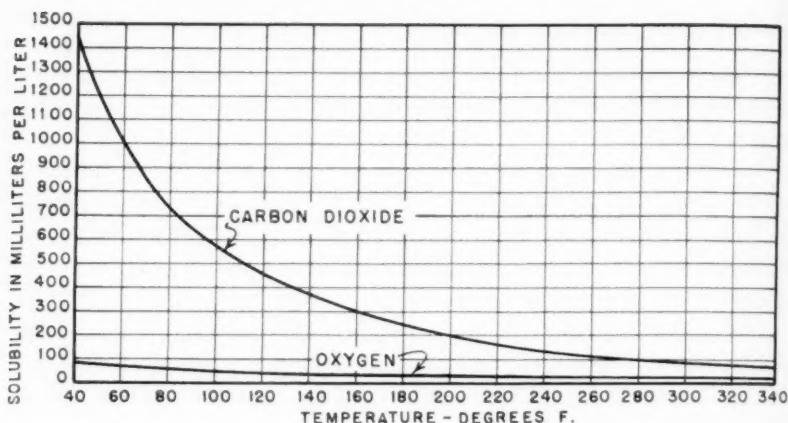


FIG. 1. Solubility of oxygen and carbon dioxide in water in milliliters per liter based on one atmosphere partial pressure, after McKay and Worthington, *Corrosion Resistance of Metals and Alloys*, p. 229.

Oxygen and carbon dioxide are sources of corrosive action in pipes and containers, particularly wherever hot water or steam is being handled. Both oxygen and carbon dioxide are quite soluble in cold water but materially less so in hot water as may be seen in Fig. 1. Consequently, water, with these gases in solution, upon being heated releases them.

It can be demonstrated by a simple experiment that both of these gases are cathodic to iron and steel, consequently free oxygen or free carbon dioxide in water and in contact with the inside of a boiler or pipe will set up galvanic action corrosive to the metal.

Efforts to correlate pH with this action have not been entirely successful. Figure 2 demonstrates the fact that over a wide range

the pH of the water has no appreciable effect on the corrosion rate whereas the presence of oxygen produces variations in corrosion. Iron may be submerged in water and if all air or other gas is excluded and the container sealed, corrosion will not take place. Metal in air if absolutely dry will not rust.

It should not be assumed from this that hydrogen ion concentration may be ignored entirely in corrosion analysis, for when taken in combination with other observed phenomena it can be quite useful as a means of detecting possible corrosive conditions. Similarly the electrical conductivity of the electrolyte can serve as an indication of corrosive conditions. The greater the conductivity the greater the corrosion, other conditions being favorable.

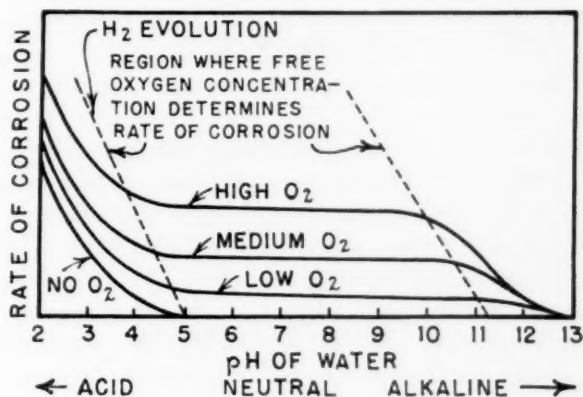


FIG. 2, after *Power Tax*, Sept., 1939, p. 27

Temperature is another of the factors controlling the rate in corrosion reactions. As the temperature of water rises the natural rate of corrosion speeds up due to increased ionization, gases released from solution, mobility of all reacting bodies, diffusion rates and lower viscosity of the liquid.

Free oxygen, free carbon dioxide, and free acid or acid generating salts are the controlling factors of corrosion by natural waters in pipe lines and conduits. Free oxygen is derived mainly from the atmosphere and goes into solution at about 6 cubic centimeters per liter; it does not ionize and exists as a molecule, O₂. Natural ground waters that have been in contact with the air and decomposed vegetable matter for some time will usually contain not over 10 parts per

million of carbon dioxide; it is about 10 times more soluble in water than oxygen and ionizes as CO_2 .

Free carbon dioxide in the amount found in natural waters is not in itself usually a factor of much importance; however, tests show that compared with the rate of corrosion in water saturated with air, the addition of 15 per cent carbon dioxide doubled the rate while water saturated with carbon dioxide (without air) was only one third as corrosive.

Corrosion by gases, oxygen and carbon dioxide, is a problem of considerable importance in hot water vessels. As shown by Fig. 1 these gases are much more soluble in cold than in hot water. Heating releases the gas and unless there is a protective deposit on the inner surface corrosion results.

Tuberculation

Tuberculation is probably one of the greatest sources of trouble in distribution systems.

The appearance of tuberculated pipes is familiar. Tuberculation may be described as a combination of corrosion and incrustation. The extent of the corrosion is minor, producing only small pits or corroded areas under the tubercle. The tubercles themselves are frequently cone-like and resemble barnacles; they grow by the addition of concentric layers and have a central portion, usually black and soft when fresh. This central portion frequently contains a small percentage of sulfide of iron which becomes red upon exposure to air. The outer layers are for the most part composed of ferric oxide interspersed with hard black layers of magnetic oxide. It is not unusual to find tubercles several inches in diameter and thickness and if left untouched these would ultimately close the inside of the pipe.

A generally accepted theory regarding the formation of tubercles is that they are formed by an iron consuming or iron depositing bacteria, such as *Crenothrix*.

If the pipe is coated, it is evidently necessary for at least a minute portion of the iron pipe surface to be exposed. It is then assumed that these bacteria gain foothold on the pipe surface where localized iron concentration is high and there colonize and form a tubercle. In uncoated pipe the action is more general, not being confined to any one location.

Once a footing is secured, the rate of development depends upon

the amount of suitable food in the form of iron in the water and apparently a suitable pH value. For conditions that favor the growth of tubercles, the water should be slightly acid (pH less than 7) and should contain in excess of 2 p.p.m. of iron in solution.

The assumption is that these tubercle deposits grow from iron assimilated by the bacteria which is subsequently eliminated as ferrous hydroxide in a sheath surrounding the bacteria. Later this is oxidized to ferric hydroxide by dissolved oxygen in the water.

From all evidence, it is apparent that tuberculation may set in without simultaneous corrosion of the pipe being noted, that is, provided that the iron-depositing bacteria may get their iron from the water which is flowing through the pipe.

It has been found that in places where the velocity of the water is greatest, a greater amount of tuberculation is present. This condition is ascribed to the greater total weight of iron passing through in the increased flow with the consequent increase in the deposition by the organisms.

Most authors agree that tuberculation is the result of iron-depositing bacteria; some state that chemical action plays a minor part; however, it is the opinion of the writer that electro-chemical action plays an important rôle in the primary formation and development of tubercles.

Dezincification

Dezincification of brass pipe is the third form of corrosion for consideration. Copper alloy pipes are replacing former iron pipe installations in old and new work to avoid iron corrosion difficulties, particularly where the temperature of the water is raised above that generally used. In piping material of this kind, dezincification may take place if the proper selection of pipe for the specific purpose is not made.

As the name implies, dezincification of brass pipe is the process whereby the zinc is removed from the copper-zinc alloy. The theory of the mechanism of dezincification assumes that brass dissolves as a whole, the dissolved copper is held in contact with the brass by a membrane and the copper is re-deposited, leaving a pipe of low strength composed of a spongy mass of copper. Dezincification is limited to yellow or high zinc brasses and is not found in brasses with a zinc content of less than 15 per cent.

This action occurs in certain waters and particularly in hot water

pipes or condenser tubing where the water carries free mineral acids or acid forming salts with oxygen present.

Protective coatings retard dezincification only in a limited range, about pH 7.5 to 9.5.

Carbonic acid and similar volatile acids have a dissolving action on brass, copper and other nonferrous metals used in steam lines and turbine construction.

The presence of oxygen or of a comparatively highly ionized copper in solution appears necessary to initiate selective corrosion (dezincification). Speller states "brass was found to corrode in hot city water with its normal content of dissolved oxygen about ten times as rapidly as in the same water with most of the oxygen removed . . . and that dezincification was much more rapid in the presence of oxygen."

Bengoregh and Hudson of the British Corrosion Committee state "as regards 70:30 brass, the normal action in ordinary types of neutral or nearly neutral water is predominantly one of oxidation, and the action of couples, if such exist, is too seriously hampered to be effective."

It should be remembered that both oxygen and copper are below zinc in the electro-chemical series and both are therefore cathodic and zinc anodic. It is our opinion that the true explanation of dezincification is that it is galvanic electrolysis resulting in removal of the zinc from the alloy. With the higher copper brasses containing 85 per cent or more copper, dezincification ceases to be a problem. This is probably due to the zinc being covered with copper and not exposed to the water and oxygen.

Brass is not the only alloy susceptible to this type of decomposition. Copper-aluminum, 70:30; manganese-copper, 25-75; and cadmium-magnesium, 85.7-14.3 were found to be subject to selective corrosion, and from experimental evidence, it is concluded that with the exception of 85 to 90 per cent or more of copper alloys, the commercial brasses are subject to dezincification.

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Corrosion Control

By Oscar C. Blumberg

DURING the last fifteen years great strides have been made in controlling internal corrosion. The principal advances have been the development of protective coatings, either mechanically applied or deposited by chemical treatment of the water.

The control of internal corrosion, in water works practice, is based entirely on the fact that no bare metal should come into intimate contact with water. If metallic surfaces are covered by a coating of some kind, the rate of attack by corrosive agents is reduced to an extent which depends on the permeability of the coating.

Protective coatings may be produced by the deposition of substances naturally present in the water. Deposits of organic material, for example, may retard corrosion by the formation of a film which is more or less impervious. Protection of this sort, however, is accidental and is usually the result of some condition which is otherwise undesirable. Silt and clay, when uniformly and compactly deposited, also afford a certain degree of protection.

Corrosion products tend to form protective coatings when deposited under certain conditions. Laboratory workers (1, 2, 3) probing this phase of the corrosion problem have shown that a dense gelatinous coating of ferric hydroxide retards corrosion. Low pH values, high flow velocities, and high oxygen concentration, all of which are ordinarily conducive to rapid corrosion, favor the formation of this type of coating. Perhaps this accounts for the absence of serious red water conditions in some systems where the characteristics of the supply are such that aggressive action should be expected.

In their manufacture, pipes are lined with various materials, such as cement and compounds of an asphaltic nature, to prevent corro-

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sion. Cement linings may be installed in existing pipe lines, using the Perkins-Gillespie system for lines 36 in. or larger, and the Tate process for lines of smaller diameter.

Another type of mechanically applied protection is that of galvanizing. Zinc, however, is also susceptible to corrosive attack, and its life in corrosive waters is definitely limited. That is why galvanized pipe is being replaced by copper pipe for service connections and household plumbing, and by cement lined cast-iron pipe in distribution systems.

Lead and lead lined pipe are likewise susceptible to corrosion. This leads eventually to attack of the underlying metal and occasionally to the dissolving of enough lead to make water toxic and therefore unsafe for domestic consumption.

Referring now to the protection brought about by chemical treatment, our interest rests principally in the deposition of a protective film on pipe surfaces. Chemicals used for some time for this purpose are either lime, soda ash, or caustic soda. However, other chemicals may be added to water to provide a protective coating. Sodium silicate, which tends to form a coating consisting of an insoluble silicate, is also being used. This has proved satisfactory in special cases, such as in the treatment of waters softened by the zeolite process (4).

The presence of an appreciable amount of silica, whether present naturally or added artificially, makes for a more impervious carbonate coating. Waters softened with lime and soda generally have their silica content greatly reduced, the average reduction in seven Ohio plants being 38 per cent (4), and at the softening plant in San Mateo (Calif.) it runs close to 70 per cent. Hence, if silica is an important constituent of the protective coating of calcium carbonate, it might be desirable in some cases to replace the loss by treating the finished water with sodium silicate.

The use of sodium hexametaphosphate for corrosion control has been recently suggested. This suggestion appears a little surprising inasmuch as its use in connection with the so-called "threshold treatment" prevents the deposition of calcium carbonate. In corrosion control the use of sodium hexametaphosphate is based on the assumption that it is strongly adsorbed by metals and metal oxides, forming a very thin film which helps to prevent corrosive attack of the underlying surfaces. Furthermore, it is claimed that this

treatment reduces trouble with red water by preventing the precipitation of small amounts of iron from solution.

Corrosion Control by Calcium Carbonate Deposition

The first real contribution to corrosion control by the precipitation of calcium carbonate was the Baylis study (5) which showed, for various alkalinities, the pH values required for calcium carbonate equilibrium, the pH required to produce a carbonate coating, and the pH required to eliminate "red water." These curves are based on the solubility of calcium carbonate in distilled water and are of practical value in determining approximately how the water should be treated in order to bring about either of the indicated conditions.

The next development was the so-called "marble test," which has since come into common use and acquired the more accurate title of "Carbonate Stability Test." This test is described in *Standard Methods of Water Analysis*, 8th edition, and is widely used in controlling the treatment of aggressive water. The marble test is used to determine whether the finished water is properly saturated with calcium carbonate. If the test results show an insufficient degree of saturation, it is necessary to adjust the chemical treatment on a trial and error basis, changing the dose and repeating the test until equilibrium is established.

To eliminate trial and error control, McLaughlin (6) has developed a procedure whereby the final pH, or the pH to work for in adjusting the chemical treatment, can be determined by dosing a sample of untreated water with increasing amounts of lime. Stability tests and pH determinations are made after each addition of lime, and results of the stability tests, recorded as plus or minus changes in alkalinity, are plotted against corresponding pH values. The equilibrium pH, or the pH to work for, occurs on the graph at that point where the change in alkalinity is zero.

The attractive feature of McLaughlin's method is that it simplifies control of the treatment process. By making a test every time there is a material change in the raw water alkalinity, enough data can be accumulated to plot a curve showing equilibrium pH values corresponding to various alkalinities. After that all an operator has to do is determine the raw water alkalinity and adjust the lime dose to maintain the pH indicated by the curve. The important difference between this and the Baylis curve is that the resulting change in alkalinity is of no consequence. If the final pH is what the curve

calls for, the operator knows that enough lime is being used to keep the water saturated or slightly supersaturated with calcium carbonate.

A recent modification of the stability test is the Enslow Continuous Stability Indicator (7, 8). This consists of two tubes, the first containing powdered calcium carbonate and the second granular calcium carbonate, through which the lime treated filtered water is allowed to flow continuously at a low rate. If the dose is properly adjusted, passage through the tube causes no change in pH or alkalinity. If an increase occurs, more lime is needed, and a decrease, of course, means that the dose is too high.

Perhaps the most valuable contribution to corrosion control is the work of Langelier on the Saturation Index and his formula for calculating the pH of carbonate saturation (9). The saturation pH, or pH_s , is a hypothetical quantity representing the pH at equilibrium, assuming no change in chemical composition. The saturation index, on the other hand, is the difference between this computed value and the actual pH of the water. If this difference is zero, the water is saturated with calcium carbonate and is therefore unlikely to be corrosive. However, if the actual pH is less than pH_s , the water has a corrosive tendency and corrective treatment should be applied accordingly.

The amount of treatment required to produce a zero index may be determined by treating portions of water with known amounts of lime, and by making alkalinity and pH tests on each of the treated portions. It is necessary also, and this makes the method a little awkward, to compute pH_s for each of the treated portions. This can be done by means of the Langelier formula, using the table and charts given in the original paper, or by using the nomographic chart developed by Hoover (10). In either case, calcium and total solids for each portion can be readily determined by computing the quantities equivalent to the applied dose and adding those quantities to the amounts indicated by the original analysis of the untreated water.

A complete chemical analysis is not necessary to solve the Langelier formula. For example, total dissolved solids in a given water may be estimated by preparing a curve showing the relation of total solids to the chloride content, or preferably to the electrical conductivity. If such a curve is available, it takes very little time to make a reasonably accurate determination. Calcium can also be determined in a

hurry, using the Brown-Villarruz modification of the soap test for total hardness (11). In this connection it might be of interest to note that a 5 per cent error in estimating the calcium content would make a change of only 0.02 in the pH_s result. Likewise, a 10 per cent error in estimating total solids would also affect the final value by 0.02 pH units.

With reference to the actual treatment which is needed to produce a protective coating of calcium carbonate, there is nothing in the literature, aside from the Baylis curves, to indicate what excess is desirable above that required for carbonate equilibrium. If we assume, however, that precipitation in the system calls for an excess at the plant of 10 p.p.m. of calcium carbonate, treatment should be regulated to maintain the Langelier indices shown in Table 1. It is a little difficult to express in practical terms the derivation as well as

TABLE 1
Langelier Indices

pH_s	LANGELIER INDEX
9.1	+0.6
8.7	+0.35
8.3	+0.15
7.8	+0.10
7.4	+0.05
6.9	+0.03

the significance of this table. What it tries to convey is the same or similar information as that indicated by the difference between the top two of the Baylis curves. For example, if it is found after treatment that the pH_s is 8.3, then the actual pH of the treated water should be 8.3 plus 0.15, or 8.45, and the lime dose must be adjusted accordingly.

Practical Methods for the Study of Corrosion

Many attempts have been made to study on a small scale the efficiency of the treatment for controlling corrosive action. This work has varied all the way from the simple placing of nails or iron filings in a flask of treated water up to complicated arrangements involving special preparation of metal specimens and careful control of conditions conducive to corrosion. Tests have also been made on pipe specimens of various lengths and sizes.

In studies relating to the effect of the treatment process, it is important to remember that we are interested in the protective qualities of a chemically deposited film. Accordingly, therefore, the experimental set-up should allow for the proper formation of this film. When metal specimens or iron filings are submerged in either an open or closed vessel containing treated water, the observed results are likely to be misleading because the total amount of carbonate available is limited and conditions are such that it is usually impossible to bring about the deposition of a protective coating. The presence of dissolved oxygen, furthermore, permits active attack of the unprotected metal and induces corrosion at a rate which is far in excess of that likely to be encountered in a normal distribution system. Oxygen corrosion, in fact, is usually so severe that it is extremely difficult to determine the effect of other conditions which might have some bearing on the rate of attack.

Experimental set-ups which simulate actual field conditions are obviously the most desirable. Tests involving pipe sections of suitable length fall in this category, although it is difficult usually to duplicate flow conditions as they actually exist in the distribution system. But in all such work, irrespective of whether it involves metal specimens or sections of pipe, it is important that the different variables be accurately controlled and that the results be carefully interpreted.

Results of laboratory experiments may be evaluated by noting:

1. The appearance of the metal specimen;
2. The decrease in dissolved oxygen concentration;
3. The increase in iron content;
4. The loss in weight of the metal specimen;
5. The increase in resistance to flow.

Information of the above nature is usually more applicable to the academic or theoretical aspects of corrosion. From a practical point of view, however, which means measuring the efficiency of the corrective treatment, results may best be gaged by field observations. These include enumeration of red water complaints and the determination of pH changes, changes in iron content, and dissolved oxygen reduction. The periodic determination of flow coefficients will also serve to reveal the intensity of corrosive activity and the effect thereon of the corrective treatment.

It should be noted in conclusion that there is still a lot to be learned about the causes and the methods of preventing corrosive action.

While definite progress has been made, the work to be done in this field is practically unlimited.

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Outline of the Corrosion Problem in Water Works

By George D. Norcom

CORROSION of metals is a familiar phenomenon in all walks of life and all kinds of industry. With the possible exception of the noble metals, the chemical processes of Nature seem bent on destroying all of those metals which man has painstakingly learned to extract from their ores. Every water works man has seen the ravages of corrosion because the production and distribution of a water supply involves the use of pumps, pipe lines, tanks, and numerous other devices which are constructed very largely of metals. These are all constantly in contact with water; many of them are exposed to the atmosphere; and the principal pipe lines are buried in the soil. Thus, water works materials are subject to underwater, atmospheric, and soil corrosion. Both from the point of view of economy, as well as quality of product, it is of great importance for water works men to recognize this universal enemy and to take such steps as are available to hold it in check. In this paper an attempt will be made to discuss briefly some of the principal aspects of corrosion in the water works system, with particular emphasis on underwater corrosion, and to indicate briefly some methods of control.

A discussion of the theories underlying corrosion is beyond the scope of this paper. Those who are interested in studying these theories will find a vast amount of material available in Speller's book, *Corrosion, Causes and Prevention*, and in numerous technical articles. Water works men are interested principally in corrosion by fresh water where only water and oxygen are essential.

It is important to remember the fundamental fact that in many cases water itself is the only chemical necessary to start the attack on a metal. In such cases water behaves as an acid, forming ferrous

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hydroxide and liberating hydrogen which is polarized on the metal surface. This hydrogen is usually removed by reaction with dissolved oxygen to form water and the ferrous hydroxide is oxidized to form rust. If the water is acid (low pH) much of the rust as well as some iron in solution will be carried through the distribution system, causing "red water." If the water is alkaline (high pH) it is probable that much of the rust will be deposited on the pipe walls as scale, which offers some protection against further corrosion but may result in serious loss of carrying capacity. These brief statements are true in a general sense, but they do not begin to cover this intricate subject since in everyday practice corrosion does not follow any fixed course and circumstances vary in every instance.

It is superfluous to attempt a listing of the many well known detrimental effects of corrosion in a water works system. Of the most aggravating effects are consumers' complaints of rusty water, stained linen and porcelain, and the inability to make good tea or coffee. More insidious and much more serious effects are the failure of service pipes, the tuberculation of iron and steel mains, the rusting of standpipes, and the deterioration of metals in general.

Relation of Quality of Water to Corrosive Action

Most natural waters are more or less corrosive to metals and too much importance should not be attached to the results of a water analysis in forecasting corrosive tendencies. It is unusual for a water analysis to show the most important factor in corrosion: namely, the dissolved oxygen. Other important constituents include total fixed solids, hardness, free carbon dioxide, alkalinity, pH, and organic content.

If water contains any dissolved oxygen or can acquire any in its passage from source to consumer, it is likely to be corrosive, and in the absence of protection the extent of its activity will be in proportion to its oxygen content. Soft waters which are high in free carbon dioxide are generally corrosive and this effect is intensified by the presence of oxygen. Other factors in water quality which favor corrosion would include low hardness, alkalinity, and pH. Factors tending to retard corrosion include protective films or coatings on the metal surface, high hardness, alkalinity, pH, and the presence of certain organic materials.

The study of corrosion prevention is largely a study of protective coatings. These may be formed as the natural products of corrosion,

they may be chemically induced, or they may be mechanically applied.

Control of Corrosion by Water Treatment

Since it is well established that continued corrosion is very largely caused by oxygen, it would appear obvious that the most important step in corrosion control would be the removal of oxygen from the water and the prevention of its absorption at any point in the distribution system. Full recognition is given to this principle in the industrial field where deaeration is common practice in boiler feed water treatment. So far as the writer is aware, deaeration of a municipal water supply to prevent corrosion has never been attempted in this country, although it was tried in Australia. The nearest approach seems to have been Powell's deaeration of an industrial supply in Louisiana. A study of this method for municipal application indicates that the most important drawbacks are the cost of the installation and the danger of re-aeration in open tanks and standpipes.

The most common method of water treatment for the purpose of decreasing the corrosive action of water is the addition of alkalis, generally lime but often soda ash or caustic soda. The theory underlying this method involves the conception of a protective coating of calcium carbonate laid down on the pipe by water which is supersaturated with respect to this chemical. After the coating is formed, the water is maintained in chemical balance on the theory that the coating will neither be dissolved nor augmented in thickness. The pH of chemical balance, or pH_n , can be determined by bottle tests, as described by McLaughlin and others, by the methods advocated by Langelier, or by the use of the Enslow saturator. It can be maintained in the water undergoing treatment by careful pH control.

Unfortunately, observations on the effect of this treatment have demonstrated that it will not entirely control corrosion. The coatings which form are not pure calcium carbonate, but compounds or mixtures of several substances; they are usually soft, mushy, and pervious to water. It has been shown that tuberculation can take place in a water treated to secure chemical balance and that tubercles will form in spite of the "protective coating." It looks very much as though the principal value of this coating is to provide an alkaline zone at the metal surface so that corrosion may be retarded and the products of corrosion may be precipitated as they are formed. This would tend to explain the fact that alkali treatment seems to correct

red water conditions because instead of the iron being dissolved and carried away it would be deposited largely in situ. In spite of its limitations, alkali treatment remains the cheapest and simplest method of corrective water treatment readily available at present.

There are at least two additional chemical treatments which are being used for the correction of corrosion: namely, sodium silicate and sodium hexametaphosphate. Both of these compounds are alkaline and in this respect their action may be somewhat similar to the more commonly used alkalis. In the case of sodium silicate it is claimed that a film is formed by inter-action with the ferrous hydroxide formed by the first step in corrosion. In the case of sodium hexametaphosphate a "threshold treatment" is proposed whereby some of the phosphate is said to be physically adsorbed on the surface of the metal, thereby offering a film of protection. Sodium silicate has been used for corrosion prevention in a number of instances and some observers report success with it. The phosphate treatment of municipal supplies is just emerging from the experimental stage and at present it looks promising. At this writing no method of water treatment has been perfected which will give universal protection against tuberculation.

Pipe Line Materials and Corrosion

The use of cast-iron pipe for distribution mains is almost universal and much of the pipe which has been laid in the past is protected only by tar dip. Experience with this kind of pipe throughout the country indicates that it is subject to corrosion and tuberculation which result in losses of carrying capacity with varying intensity for different waters, but the thickness of this pipe is so great that it rarely fails from the destructive effects of corrosion. For many years engineers have experimented with protective coatings to preserve the carrying capacity of the pipe, and the use of cement linings and spun bituminous linings is becoming more popular as time goes on. Steel mains are perhaps less, and certainly no more, resistant to corrosion than cast-iron, so that here again protective linings should be worth far more than their cost. Concrete and cement-asbestos pipe is not subject to tuberculation, and the tendency of water to leach the lime out of these materials seems to be self limiting to a large extent. This leaching action should be partially offset, at least, by seal coats of asphalt or refined tar.

It is not the intention of this paper to discuss soil corrosion, but in

passing it should be mentioned that certain soils exert a highly corrosive effect on metals, and where mains are laid in this type of soil some protection should be provided against external corrosion. Certain manufacturers are in a position to supply protective coatings and wrappings, and these seem to have found considerable favor in the gas industry. When mains are laid in acid soil it is a common practice to surround the main with an alkaline material, such as limestone and sand, or with some other non-corrosive soil before backfilling. A new application of an old method of corrosion prevention is being attempted on certain steel pipe lines by utilizing direct electric current for reversing the polarity of the metal.

Corrosion and Choice of Service Line Materials

Service pipe is available in a number of materials, the most popular being iron and steel (plain or galvanized), brass, bronze, copper, lead, and cast iron. Iron, steel, and cast-iron service pipes are also available with special protective linings. Cast iron is not available in the small sizes, but is often used in lines from 1½ inch up. In a general way the preceding statements regarding iron and steel mains are applicable to smaller iron pipes. Yellow brass is not a very desirable material for service pipe since it is attacked both by acid and by highly alkaline waters and frequently fails because of dezincification. It is used successfully in some water supplies. Of much more universal use, particularly in corrosive water, is red brass containing about 85 per cent copper. Bronze does not seem to have any particular advantage over red brass. Pure copper tubing has replaced iron pipe in many plants and is a very satisfactory service pipe material. Under some soil conditions copper tubing appears to become brittle, but this occurs so rarely as to be of minor importance. In very soft corrosive waters the red brass and copper piping are sometimes attacked to such an extent that slight greenish stains are formed on porcelain, but it is safe to say that if sufficient copper were present in any water supply to be detrimental to health the water would probably be unpalatable. Lead pipe was once very popular and a great deal of it is still in common use. Lead-lined galvanized iron pipe has also found favor in certain sections of the country. Under proper conditions lead possesses long life and has proved very satisfactory, but there is a serious drawback to its use, namely, the fact that its salts are quite poisonous. Lead or lead-lined pipe should never be used in a water supply which is plumbo-

solvent and any tendency in this direction should be carefully determined by experiment before this material is utilized for service piping.

Standpipes and Steel Tanks

In the case of standpipes and steel tanks the water works operator is faced with atmospheric corrosion on the outside and underwater corrosion on the inside, augmented by a free access of oxygen. In warm climates where there is no danger of ice action, the use of hot bituminous applications is said to be very satisfactory and thin cement coatings have also been used on the inside of tanks. The more common practice is to paint the inside of the standpipes with various materials, particularly those possessing water-repellent qualities, but an entirely satisfactory paint for this purpose remains to be discovered. Present practice seems to consist of red lead or chromate priming coats, followed by top coats either of aluminum or of paint containing synthetic resin, asphalt or graphite.

The outside of standpipes and tanks is usually protected by painting, and here appearance is as important as protection. It is not to be expected that any paint will permanently remain on a metal surface exposed to the weather; consequently, standpipe maintenance usually requires painting every three to five years. This is a most important item of recurring expense and a satisfactory method for its elimination is highly desirable. Efforts are being made to solve this problem electrolytically and the possibility of sprayed corrosion-resisting coatings of metal has been suggested.

Corrosion of Meters and Valves

The problem of the corrosion of meters is usually met by the use of special alloys developed as a result of study of the particular water supply in question. Manufacturers have always been very co-operative in this field. Perhaps at some future time we shall be treated to the prospect of a meter constructed entirely of non-corrodible material and possibly provided with a porcelain or similar lining.

Valves are obtainable with certain bronze moving parts and the writer believes it is possible to have all working parts of this metal if water conditions make it necessary. Pumps can be secured with porcelain linings, bronze or stainless steel shafting and runners, and numerous other refinements so that corrosion may be reduced or

entirely eliminated. Filter manifolds can be constructed of concrete, glass, and corrosion-resisting metals and alloys, which is equally true of most water works appurtenances. For handling corrosive solutions of water purification chemicals, such as alum, ferric chloride, iron sulfate, chlorine, etc., the following special materials are commonly used: concrete, rubber and rubber linings, glass, stoneware, high silicon iron, high chromium and nickel steels, lead, and lead linings.

In this paper an attempt has been made to give a brief and elementary discussion of the corrosion problem in the water works field and some practical methods which are commonly used to control it. In spite of the study which has been given to the corrosion problem, it is apparent that it is a long way from being solved. Every water works man should study corrosion in his own plant, determine the remedies which seem best suited to his conditions, and then apply them.



Corrosion of Consumers' Plumbing

By Robert R. Ashline

MANUFACTURERS of water heaters, refrigerators, and plumbing fixtures test their products at the factory under conditions presumed to be representative of operating conditions to which they will be subjected in actual service. Some of these tests are so-called accelerated tests, which supposedly impose conditions representative of many years of ordinary service use, but under the artificial conditions of the tests they are applied and run to completion in a few days or a few weeks. When the products are installed on the consumer's premises conditions of operation are inevitably very different from those under which the tests were applied. In fact, no two sets of conditions are ever exactly alike and consequently the accelerated tests run at the factory must be interpreted in terms of "probable service life" under the particular conditions of use.

When failures resulting from corrosion of his plumbing and appliances occur in less than the reasonably anticipated service life of the equipment, the consumer immediately concludes that he has been sold an inferior product, or that his is the one chance sub-standard item from a factory lot. On this basis of inference he protests to the plumber who sold him the product and installed it for him. He is in turn referred by the plumber to the manufacturer. The manufacturer sends an inspector to investigate the complaint and to determine, if possible, the cause of failure. The inspector knows that the representative product was thoroughly tested at the factory, and unless the contributory cause of failure is readily apparent he explains to the customer that the trouble "must be caused by electrolysis, or possibly by corrosive chemicals contained in the domestic water supply." The consumer is advised by him to take the matter

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up with the water company, since the assumed cause of failure is beyond the manufacturer's control and only the water company can alter the quality of the water delivered, or do anything to stop electrolysis effectively.

Opportunity for Improvement of Consumer Relations

Armed with the information (often misinformation) given him by the manufacturer's representative, the consumer proceeds to explain to the water company all about the troubles and damages being caused for him by the "bad water" he is getting, plus that vague something called "electrolysis." This is the point at which the water company must not only be tactful but also genuinely helpful if public confidence and good consumer relations are to be maintained. This is where the vicious circle of "passing the buck" can and should be broken. Since the water company is striving to render the best possible service to all of the people and is not concerned with the special interests of any particular group of people aside from any other group, its representatives can look upon the problems presented from an impartial and unbiased point of view. An opportunity for the water company to enhance the value of its service to the public is thus introduced.

The Bureau of Water Works and Supply of the City of Los Angeles has consistently endeavored to ascertain the real causes of failures in consumers' plumbing served with Los Angeles city water. Whenever there appeared to be any possibility that stray current electrolysis might be caused by any detail in operation of the water distribution system, tests have been made by the Bureau to ascertain whether or not such possibility were a fact. Although many individual tests have been made for stray current electrolytic potentials, and for flows of electric current on water service connections, during the past ten years not more than half a dozen instances of stray electric currents traveling over the water mains to consumers' premises have been found to be even remotely involved. These were at once corrected by installation of insulating joints, or other appropriate remedies were applied.

Frequently corrosion of consumers' plumbing has shown evidence of electrolytic action, which in most instances was found to be of galvanic origin. The extensive experience of the Bureau with the dissimilar metals problem has often furnished the clue as to causes and possible remedies applicable to consumers' corrosion troubles.

Such information as might prove helpful has been passed on to the consumer, and to the manufacturer of his equipment, when similarity of conditions was apparent and remedies found successful by the Bureau might also aid in solving the consumer's corrosion problems. Results indicated by these investigations have led to classification of the types of corrosion and failures observed, together with general recommendations for their correction or mitigation. These classifications are:

- (1) Stray current electrolysis (rare),
- (2) Corrosive water and tuberculation,
- (3) Poor galvanizing (zinc-iron electrolytic couples),
- (4) Dezincification of brass pipe (micro-galvanic corrosion),
- (5) Use of dissimilar metals (galvanic action and thermocouple effects),
- (6) Use of water softeners (electrolytic concentration cells),
- (7) High pressure high velocity flows of water that dislodge protective scale of corrosion products, thus exposing underlying metal to further corrosive attack, and
- (8) Leakage of refrigerant at joints and connections (acid attack on metal).

Remedies

(1) Stray current electrolysis problems will never entirely disappear so long as electric railways, powered with direct current motors, are the accepted means of public transportation. The corrosion of metallic pipe lines caused by leakage currents from electric railways can only be controlled and minimized by continuous co-operation of the railways with the substructure owning utilities, and involves engineering difficulties beyond the ability of any one organization to contend with alone. In Los Angeles stray current electrolysis has been greatly reduced in recent years, but it has by no means been eliminated.

(2) Corrosive water and tuberculation have been discussed by others in this symposium, hence no special discussion need be presented here.

(3) Corrosion troubles caused by poor galvanizing of hot water tanks, pipes and plumbing fixtures can be greatly reduced by insistence upon better specifications. Galvanized iron should not be accepted unless the galvanizing is uniformly heavy and the zinc is sufficiently thick to equal at least two ounces of zinc per square foot in thickness. Standard tests should be developed and prescribed

for proving absence of pinholing in the galvanizing. The ferroxyl test should be adaptable to and adequate for this determination if properly applied. Unless galvanized iron can pass such rigid tests it will be susceptible to concentrated corrosive attack at any weak or thin points in the galvanizing. Corrosion will be accelerated at such points by formation of zinc-iron (galvanic) couples through aqueous solutions of electrolytes, similar in behavior to the electrochemical action of the well-known voltaic cell. The zinc disappears, exposing the iron beneath. This has been the most common cause of failure of consumers' plumbing in Los Angeles. It has been particularly troublesome in the case of hot water heaters.

(4) Dezincification of brass pipe has been one of the troublesome items of corrosion of consumers' plumbing in Los Angeles. The zinc and copper crystalline micro-structure of the matrix of the metal provides millions of microscopic anodes and cathodes, thus providing the elements for forming myriads of galvanic cells or "batteries" in the presence of aqueous solutions of electrolytes. Zinc lies in a position more than one full volt positive to copper in the electromotive series of the metals, hence it is not surprising that brass pipe becomes porous and honeycombed because of the zinc constituent dissolving out of the structural metal by electrolytic cell action.

(5) The use of dissimilar metals in the manufacture of water heaters, air-conditioning equipment, or any other plumbing fixtures should be vigorously discouraged. Every juncture between pipe and fittings made of different metals, such as between iron pipe and copper heating coils, is a potential electrolytic cell. The unavoidable one juncture at the inlet, and at the outlet connection, creates a corrosion hazard. A multiplicity of such junctures creates an inexcusable number of corrosion hazards. Junctures of brass pipe and fittings with other metals are especially objectionable because the copper constituent of brass is strongly cathodic to all but the noble metals, such as gold and platinum. Its use not only introduces electrolytic corrosion hazards for the metals to which it may be joined, but brass is itself susceptible to dezincification. In the light of present knowledge of its corrosive behavior, the use of brass tubes for inlets or outlets to hot water tanks is positively inexcusable. Its lower first cost can never justify the many times greater costs of property damages; the excessive costs of tearing out expensive tile and terrazzo floors for making repairs; nor the costly interruptions to service resulting from early and frequent failures.

Wherever a juncture between dissimilar metals cannot be avoided (a multiplicity of them should never be tolerated) an electrolytically insulating protective coating should be applied over the joint, and should be extended well past the juncture point in both directions. The protective application should be tested for complete coverage and absence of pinholes, so that it will shield (thus eliminate) all proximate exposed cathodic metal areas. Architects and plumbers should take care in designing each installation so that the few unavoidable junctures between dissimilar metals shall be at points where the fluids contained are least subject to variation in dissolved chemical content as electrolytes, and where there is least rise of temperature. Heat applied at such juncture points gives rise to thermocouple electric currents which cause electrolysis of the anodic metal.

The relative thermal conductivities of iron and copper are as 0.151 is to 0.908, or about one-sixth. Fuel economy and water heating efficiency are, therefore, strong factors in favor of copper as the metal for hot water tanks and adjacent plumbing. Monel metal is less susceptible to corrosion than iron under most conditions, but its heat transfer efficiency is more nearly equivalent to that of iron than of copper.

(6) The improper use of water softeners has been the cause of a number of failures of consumers' plumbing in Los Angeles. In these cases, good quality non-corrosive water was delivered to the consumer; but his desire to reduce water hardness to an extremely low minimum caused him to apply treatment which made a corrosive water out of the non-corrosive water delivered to him.

(7) Tubercles are often formed where there are imperfections in the galvanizing of sheet iron tanks. Removal of these tubercles by surges of pressure and increased velocity of flow of water exposes the metal beneath to further corrosive attack. Reduction of excessive pressures, and prevention of abrupt changes in velocity of flow, will materially reduce the number of failures resulting from this cause of corrosion.

Protective scales of precipitated calcium carbonate interspersed with corrosion products frequently become cracked, broken, and dislodged as a result of the difference between the coefficient of expansion of metal and that of the non-metallic boiler scale formed on the insides and bottoms of hot water tanks. The low thermal conductivity of this scale results in excessive heating of the underlying

metal; changes of temperature result in discontinuities of the shielding of metal against contact with water; and sudden access of moisture through cracks in the scale results in explosive expansion of water vapor formed, thus exposing the metal to extremes of corrosive attack. The sudden chilling of superheated metal results in its sudden shrinkage and re-crystallization, which in turn starts incipient cracks in the metal plate that serve as new centers of concentrated corrosive attack. The most practical remedy for such troubles is frequent and periodic flushing out of hot water tanks, and prevention of excessive heating.

(8) Special care should be taken by manufacturers of refrigerators, and by the plumbers and/or service men who install or repair them, that all joints in the containers and piping of refrigerant are perfectly tight and leak-proof. A few instances of oversight on this important point have resulted in complaints to the Water Department. It has been found that leakage of sulfur dioxide in particular through imperfectly sealed joints into the cooling water resulted in corrosive attack on the metal by sulfurous and sulfuric acid formed by the dissolving of sulfur dioxide in the water. The remedy for such conditions is obvious.

Summary

The American Water Works Association can contribute to the prevention and correction of consumers' corrosion problems by publicizing the facts about causes of corrosion of metals. There is a distinct need for co-operative research, and publicity of the results of such research, looking to the development of better or more complete building codes, plumbing codes, and more comprehensive and flexible local regulations or ordinances. There is a wide open field for such co-operation between the Pacific coast section of the American Water Works Association and the Pacific Coast Plumbing Inspectors Association at the present time. Both organizations are striving to improve their service to the public by determining the causes of corrosion of water works and plumbing fixtures, and by searching for effective and economical remedies that will be practical in application.

Anything to better consumer relations is an asset to the water company or department.



Jacking 72-Inch Culvert Pipe Under Outfall Sewer

By Ralph Shepherd

LEADING from an 84-inch conduit, which is connected to Baltimore's Montebello Filtration Plant, there are two parallel 40-inch mains which were installed about 1876. One of these mains is tied into a 30-inch main which had been installed to provide larger quantities of water under more adequate pressures to the eastern and southeastern sections of the city; but as the territory grew faster than anticipated, an additional 36-inch main, which was thought to be unnecessary until about 1940, was started in 1935. This water main is called the Southeastern Low Service Transmission Main. It extends from the previously mentioned 40-inch main at Washington Street in a southeasterly direction to Holabird Avenue and Dundalk Avenue, a distance of 27,000 ft., where it will tie into the existing main at this point and form a loop or continuous circuit, which is most desirable in supplying large areas. The area affected is approximately ten square miles, which is now being supplied from the Bureau's distribution system.

The greater part of this main was laid in streets which were graded and comparatively free from subsurface structures which would present any difficult construction problems. However, about midway, in the course for the main, there was encountered a section approximately 500 ft. long which crossed a marsh. In January, 1939 work was started on the installation of the 36-inch main in this section. Crossing the marsh, there was a sewer right of way, approximately 45 ft. wide, known as Sewer Road. This right of way contained the outfall sewer which extends from Baltimore City to the disposal plant at Back River. This sewer ran at right angles to the Water bureau's proposed 36-inch main.

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The original plan called for tunnelling under the sewer, and preparations were made accordingly; but when a final check was made with the Bureau of Sewers to ascertain the elevations and other pertinent information, the sewer records disclosed that the sewer was a horseshoe section, 11 ft. by 12 ft. 3 in., of concrete masonry construction, without reinforcement. Also disclosed was the fact that an 8-inch terra cotta underdrain was present, the exact elevation of which was not definitely known. However, the Bureau of Sewers stated that the general practice in such cases was to install the drain approximately 18 in. below the bottom of the sewer. This, according to the water bureau's calculations, would give a clearance of approxi-

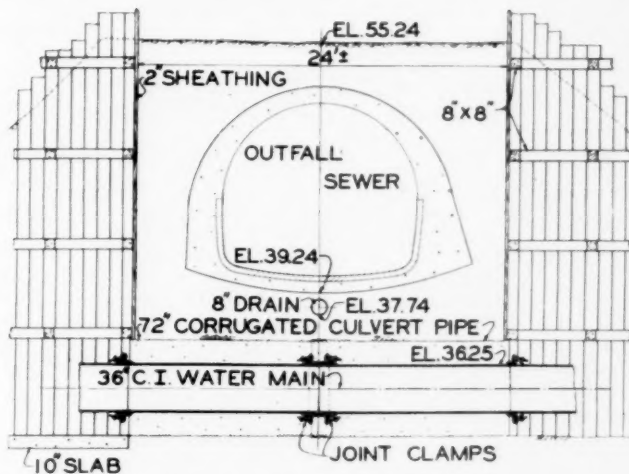


FIG. 1. Plan of the Operation

mately one foot from the bottom of the drain to the top of the proposed tunnel. It was further learned that the sewer was heavily loaded, running about 90 per cent full. This sewer is the only outlet for the entire sewage disposal from the city of Baltimore, and it was of extreme importance that no cave-in occur that would damage the sewer and interrupt the service.

Therefore, in view of these facts, it was then decided that it would be inadvisable to tunnel. Instead, it was decided to jack a 72-inch, 10-gage culvert pipe through this section, which was approximately 24 ft. long. As this was the first job of its size that this department had undertaken, a bulletin on the subject was secured from the manu-

facturer of the pipe. The information obtained was very helpful; however, it dealt for the most part with jacking pipe under ideal working conditions.

Test borings were made and disclosed that the section through which the pipe was to be jacked contained sandy soil. A test pit was then dug, and it disclosed that the upper half of the heading consisted of hard sand and the lower half, running sand.



FIG. 2. Culvert Pipe Lowered into the Trench

Work was then begun on the excavation of the approach trench in which it was necessary to conduct the jacking operations. Due to the nature of the soil, the trench, which was 25 ft. deep at this point, was sheathed solid, and as this marsh land contained a considerable amount of water, a 3-inch gasoline diaphragm pump was kept in continual operation. As the bottom was running sand, the first

consideration was to provide a dry, solid bottom on which to rest the pipe to be jacked and to have the bottom of sufficient strength to carry the 36-inch main which was to be supported thereon. This was accomplished by constructing a 4-inch underdrain with a 4-inch gravel base, on which was poured a 10-inch reenforced concrete slab, using a 1:3:4½ mix. At the lower end of this slab a 10-inch sump hole was constructed. This hole was drained by using the 3-inch diaphragm gasoline pump which was kept in operation twenty-four



FIG. 3. Bottom of the Trench Showing Jack Supports

hours daily. This solved the problem insofar as a solid, dry floor was concerned.

The next problem was to provide adequate support for the jacking operations. This was accomplished by burying two 8 in. by 8 in. by 6 ft. uprights to a depth of 2 ft., together with two 8 in. by 8 in. by 2½ ft. timber braces, in the above mentioned concrete slab. As the correct elevation and alignment in the starting of the jacking operations were most important, a liner plank, 2 in. by 10 in. by 12 ft., with a 1½-inch strap iron in its center, was set on the concrete slab to the correct elevation. Two side runners, 6 in. by 6 in. by 12 ft.,

with edges adjacent to the pipe faced with steel straps, were set in place and blocked against the side of the sheathing to insure proper alignment.

When this work had been completed, the culvert pipe, especially fabricated for jacking purposes, 12 ft. long, made up of six 2-foot sections riveted together, was lowered into the trench by means of a crane. A center line was painted on the pipe. The proper elevation and alignment were maintained by the use of batter boards and string line. A workman with a plumb bob and rule was stationed on top of

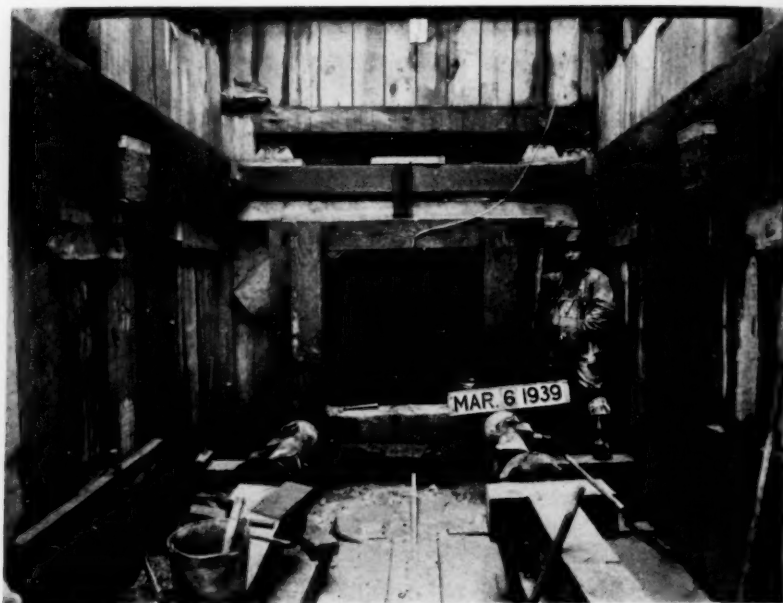


FIG. 4. A Progressive Stage in the Jacking; note bearing block on pipe and the location of the jacks

the pipe and kept a continuous check on the line and grade while jacking operations were in progress. A bearing block, which was a framework constructed by using four 8 x 8 in. timbers covering the end of the pipe, was made. The purpose of this block was to provide a uniform bearing over the entire periphery of the pipe and also to distribute evenly the pressure exerted by the jacks over the entire end of the pipe. As an adjunct to this bearing block, an iron hoop was placed around the end of the pipe and bolted in place. This tended to stiffen the pipe on the end where the force was to be applied.

The reference bulletin recommended the use of two 35-ton jacks in jacking pipes of this size; therefore, two 35-ton mechanical screw ratchet jacks were obtained and set in place. A circular cut, to the approximate diameter of the 72-inch pipe, was then made in the sheathing. When this section was removed it was discovered that the earth on the top half was not firm enough to stay in place and was beginning to cave in, leaving a void at the top of the pipe and sliding in the lower half, forming a 1 to 1 slope.

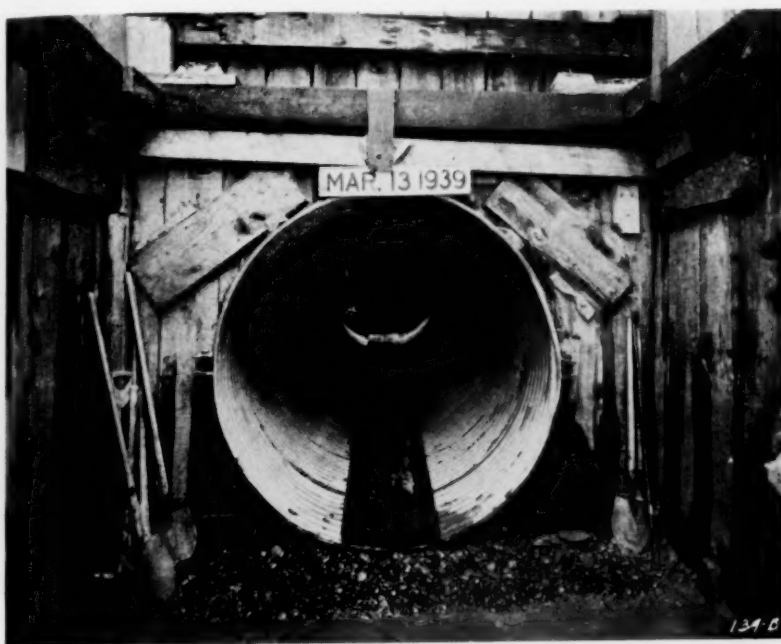


FIG. 5. The Culvert is Jacked Through

The general practice in jacking pipe is to clear two or three inches of heading approximately $1\frac{1}{2}$ in. above the top of the pipe and to excavate to the exact grade on the bottom, thereby assuring a clear passage on the bottom for the leading edge, and also to dig cross trenches at the bottom of the pipe to serve as a depository for the material which accumulates on the outside of the pipe. The material in the lower half of the heading was running sand, and it was impossible to clear this material away from the leading edge of the pipe; therefore, the jacks were lowered to within approximately 10 or 12 in.

from the bottom to take care of the increased pressure thus formed.

The 35-ton jacks were used until the culvert pipe had entered approximately four feet; then it was discovered that these jacks were of insufficient capacity to do the work, and they were replaced with two 50-ton mechanical screw ratchet jacks, which proved adequate and were used without further delay until the completion of the job. Three men were used on each jack.

These jacks had a travel of 12 in. For every 12-inch travel of the jacks the culvert pipe was advanced from 8 to 9 in., as approximately three inches of the jacks' travel was lost, due to the compression of the blocking and deflection in the jack supports.

Two men were stationed in the pipe at the heading and with hand shovels excavated approximately two inches ahead of the leading edge in the upper half of the heading. The lower half, consisting of running sand, could not be excavated ahead of the pipe and was shoveled out as the pushing operations progressed. This material was relayed to the end of the pipe and deposited in dump buckets which were lifted to the surface by a crane.

After this 12-foot section of pipe had been jacked in place, the second section, 12 ft. long, was lowered in place by crane, placed on the lining timbers, and cold riveted by means of air hammers to the section already jacked. Jacks and timbers were then replaced and jacking operations proceeded as previously stated.

The removal of dirt in this long section was accomplished by placing boards on the bottom of the pipe and using a wheelbarrow to transport the material from the heading to the open end. When operations for the day were suspended a timber bulkhead was placed in the heading to insure against cave-in, as running sand was encountered throughout the entire length of the job.

The pipe was jacked at the rate of 0.4 ft. per hour. This included jack changes, the lowering and placing of the pipe, and riveting the two sections together.

Light was provided by using a gasoline electric generating outfit with two 200-watt lamp extensions. This proved very satisfactory from the standpoint of providing adequate light and the ease with which it could be moved to points of advantage.

When the jacking of the pipe was completed, it was discovered that no material had been lost outside of the roof and sides of pipe. The pipe was found to be only $\frac{1}{2}$ in. off true center line and the correct elevation was maintained throughout.

After the two sections of pipe had been jacked in place the 36-inch cast-iron main was installed, using two 12-foot bell and spigot lengths with a sleeve in the center. The joints were poured with lead and joint clamps placed thereon.

The personnel on this job consisted of a supervising engineer, one foreman, eight laborers and one crane operator.

The condition of soil was: upper 3 ft.—hard sand; lower 3 ft.—running sand and water.

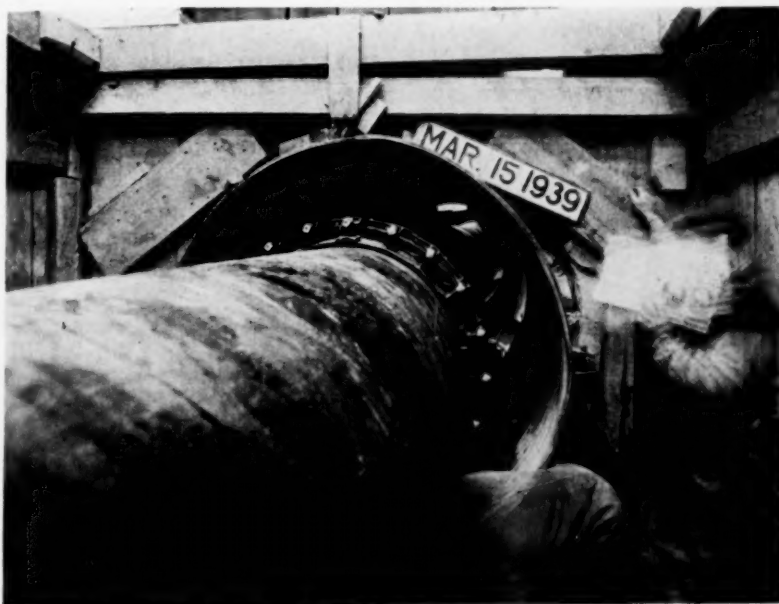


FIG. 6. The 36-Inch Cast-Iron Main Installed in the Culvert Pipe; note pipe joint clamps

The materials were: two 12-foot lengths of 10-gage, 72-inch culvert pipe, fabricated for jacking, with iron hoop.

The equipment was:

- Two 50-ton mechanical screw ratchet jacks,
- One 3-inch gasoline driven diaphragm pump,
- One 160 c.f.m. gasoline driven air compressor,
- One 3-ton gasoline driven crane,
- One air-driven riveting hammer,
- One gasoline electric generating outfit for light.

Picks, shovels, short handle shovels, sledge hammers, pinch bars.

Necessary timber and blocking for support of jacks and alignment of pipe.

It is estimated that the construction of a tunnel through this section would have cost approximately one-third more than the cost of the jacking. Therefore, the jacking of this pipe was not only more economical than tunneling, but it also practically eliminated the liability of cave-in and ultimate fracture of the sewer. As the 36-inch water main was to be encased in concrete, the saving in the amount of concrete necessary to accomplish this was considerable.

In view of the economies effected, together with the safety which the pipe afforded the workmen, the jacking operation, in our opinion, constitutes the ideal method of construction where conditions similar to those we encountered exist.



Maintenance of Pumps, Motors and Controls

By James Brower

OF THE three pumping systems in common use, that of the turbine deep well pump is commonest. The plunger pump has done worthy service in supplying small communities and this pump still has a field, even though the use of the deep well centrifugal pump is expanding. Also still in use are some air lift systems used to bring the water to a surface reservoir. From the reservoir the water is pumped by centrifugal pumps into an elevated standpipe. The distinct advantage of air lift pumping is that no moving parts are below the ground surface. Also all operating machinery for a number of quite widely scattered wells can be located in one plant with air transmission lines to the various wells and the flow of the water can be controlled by the engineer in the plant. The equipment consists of an air compressor located at any convenient point where installation expense and transmission losses are not too great, an air receiver, air transmission pipes to the wells, the pumps proper and the water piping and storage system.

It is to the advantage of the water works operator to familiarize himself as much as possible with these different types of pumping systems. This paper will give only a general outline of maintenance. We are not here concerned with the design of a water system because, in most cases, that has already been completed when the operator appears on the job. Engineers, who design and build these various plants, know that the success or failure of their work depends largely on the skill of the man who is selected to operate the plant. From the time the plant is turned over to the operator, the responsibility to supply water at the lowest possible cost rests upon the operator.

A paper presented on November 1, 1939, at the Wisconsin Section Meeting at Oshkosh, Wisconsin, by James Brower, Plant Superintendent, Milwaukee Sewerage Commission, Milwaukee.

To the author's knowledge there are, from the standpoint of lubrication, two types of pumps built today, oil-lubricated and water-lubricated. Most water-lubricated pumps have an open line shaft, with a sleeve of monel or some other metal fastened to the shaft at the point where it operates in the rubber bearing. Lignum vitae bearings have also been used, but not with any degree of success. The writer believes wooden bearings have not been generally adopted because, where sand or grit is carried along with the water, the sand imbeds itself in the pores of the wood and causes rapid wearing of the bearing diameter. This causes side whipping of the shaft especially where long line shafts are necessary due to the depth of the well. In the enclosed line shaft water-lubricated bearing, a bronze bearing studded with graphite is used. This requires a stainless steel shaft, which makes a good unit although rather expensive.

The bearings of the oil-lubricated pump are usually made of a plastic alloy bronze which, giving the ultimate in surface, is ideal for oil lubrication and will seldom freeze if the oil supply is interrupted for short periods. Most line shafts are lubricated by manually operated forced feed oil pumps, or gravity feed oil cups, attached to the pump head. Others use solenoid operated lubricators. The advantage is that lubrication starts as soon as the pump is put into operation, and stops when the pump is shut down. Where it is absolutely necessary to have oil-less lubrication and still use an enclosed line shaft, some manufacturers make a special phosphor bronze bearing. Grooves cast in the bearing surface are packed with a hard graphite lubricant. During operation a small amount of water is bypassed into the protective tubing.

When using oil it is of the greatest importance to use a high grade lubricant of the proper viscosity. Well water usually has a low temperature and therefore requires a light oil. Heavier oils would tend to increase friction with an increase of power consumption.

Where packings are necessary, only the best should be used. It is possible to obtain from the packing manufacturers rings which are already cut to fit the shaft and stuffing boxes. Packing rings should be placed staggered, so that when the ends of one ring are at the top of the stuffing box, the ends of the next ring will be at the bottom. Packing should enter the box freely; it never should have to be driven into the box. Set the gland up evenly, to drive the packing uniformly into the stuffing box, and then loosen the nuts so that they are just finger tight. A little water dripping from the bottom of the

gland is a healthy sign and shows that the packing and shaft are getting some lubrication from the water trickling through.

Protecting Shafts of Centrifugal Pumps

Where centrifugal pumps are used, we find that in a great many cases the shafts are lined with bronze sleeves. The manufacturer knows by past experience that a great many shafts have been cut by the application of wrong packing and the tendency of some operators to screw packing too tightly. In the stuffing box of centrifugal pumps there is a sealing gland or lantern. Pipes leading from the discharge of the pump are connected to the stuffing box housing. The lantern or sealing glands opening should be placed in such a manner that it comes directly under this pipe. As a rule two or more rings are placed ahead of the sealing gland. The gland is then put in position and the remainder of the stuffing box filled. The purpose of the sealing gland is to prevent the pump from sucking air through the stuffing box into the pump housing, and at the same time the packing and the shaft are lubricated. It can be readily seen that, as the packing wears and the stuffing box gland is drawn further into the stuffing box, there is a possibility that the sealing gland will be moved toward the pump housing. If the gland moves too far the sealing water will be shut off. It is a common habit, when the stuffing box starts to leak too much, merely to add one ring in the front. While this may stop the leak, the remainder of the packing may be hard and it may start cutting the sleeves or shaft. It is cheaper to repack entirely from time to time. Pumps with brass lined shafts, should be packed with a braided or built-up packing. This packing should be pregnated with a graphite lubricant. Flax or plastic packings should never be used, because cutting of the sleeves will result.

Care of Bearings

The bearings of pumps or motors should have the best of care if they are to give continuous service. Where sleeve bearings are used, the operator will find an oil reservoir to hold the oil, and rings around the shaft, hanging into the oil reservoir. When the pump or motor is started, the rings are supposed to revolve with the shaft, bringing oil to the top so as to lubricate the bearings. Sometimes these rings have a tendency not to turn, especially if the machinery has been idle for some time. If this condition is not noticed in time, a hot bearing results. A hot bearing is generally a ruined bearing, so it is

good practice to lift the inspection covers at starting and make sure that the rings are bringing oil to the shaft. The oil wells should be drained and cleaned from time to time. Necessity for cleaning will depend upon the quality of the oil used and the possibility of dust entering the bearing. A good grade of oil should be used. It may be emphasized that if you keep in mind that you are buying lubrication the price per gallon of oil becomes only secondary.

Where sleeve bearings are used on motors, care should be taken not to overfill. If you do, in the long run you will have trouble with your motor windings. Oil on the windings of a motor has caused more burned out coils than any other cause we think of. Not alone that oil drippings make a smeary mess and collect dust and dirt, oil on the floor and motor winding is a waste of money.

If ball or roller bearings are installed on pumps or motors, they are as a rule lubricated by grease, or as some call it, solidified oil. The operator should first be sure to use a grease which is recommended by the bearing manufacturer. One can generally pick from a large selection, because manufacturers have tested a great many greases under extreme conditions. The operator can be sure that any one on the approved list will fill the bill. While over-lubrication on a sleeve bearing will cause the oil to run on the floor or deposit on the motor winding, over-lubrication with grease on a ball or roller bearing will cause the bearing to run hot and cause flat spots on either the balls or rollers. Since the weight of the shaft rests on the balls or rollers, when grease is injected, in some cases with a pressure gun, the results are that the grease is packed too tightly between the moving parts of the bearing, and, instead of a rolling action, a sliding action takes place, the friction increases, friction causes heat and a hot or ruined bearing results.

Twice a year we pack the motor bearings in our plant and it is enough, if a high grade lubricant is used. If for any reason you have to take a motor equipped with roller bearings apart, be sure when reassembling, to replace the right number of shims. Remember that while you are working at the motor, it is at room temperature and that when it is operating and carrying a load, it becomes warmer and the shaft starts to expand. If insufficient clearance is provided the end bearing will become hot and ruin the bearing casing.

Motors, as well as the starting or controlling equipment, should be kept clean in order to give trouble-free service. Where a motor is directly connected to a pump or any other kind of machinery through

a flexible coupling, it should be properly lined up. This can be easily tested by first marking a line across the coupling before removing the coupling bolts. The writer recommends this because if the machine has been running without vibration, by assembling the coupling any old way, it may be out of balance, and it may vibrate when started again. When truing up a coupling, clean off all paint and burrs on the coupling. Use a straight edge and a set of feelers or a thickness gage. If no feelers are available, use a tapered hard wood stick. When the couplings are perfectly true on both faces and outside diameter, and are of the same diameter, the exact alignment will show that the distances between any points on the faces are the same at all points. If the faces are out of parallel, the thickness gage, or feelers will show a variation at different points. If one coupling is higher than the other the amount may be determined by the straight edge and feelers.

The rotor in the motor should be tested from time to time, to see that it has the proper air gap in relation to the stator, in other words to see that it is centered. By sticking a long thickness gage between the rotor and stator at the top, bottom and sides, this can easily be determined. Worn bearings will cause the rotor to drop and if this is permitted the rotor will rub on the stator, the result being an overheated motor or burned out stator.

Cleaning with Air

The dust should be blown out of motors from time to time, depending on the conditions of the surrounding air. When high pressure air is available, it may be used. Care must be taken that the air is dry so that no water is blown between the winding. Where no high pressure air is available, powerful bellows, or a vacuum cleaner may answer the purpose.

Where slip ring motors are used, care should be taken, that the brushes fit properly on the connecting rings. Brushes of the right resistance should be used and the operator should consult the manufacturers for recommendation when in doubt. In fitting a brush to the ring use sandpaper, never use emery paper as the emery may imbed in the brush and when the motor is in operation a cut or groove will be made in the collector rings. Keep the collector rings clean and the wires leading to same, free of dust. No chain is stronger than its weakest link, and while pump and motor may be in the pink of condition, the control apparatus plays a very important part in continuous operation.

Caring for Control Equipment

There are so many different types of control on the market, that it would be impossible to mention them here. It is important first of all, that all connections leading to the control be kept clean and tied and that the contacts of switches, breakers and automatic starters make the proper contact over the entire surface for which they were designed. Contacts or switches have the annoying faculty of oxidizing in service due to fumes or gases in the air. If this takes place, heating results. It is a good practice, when machinery is shut down, to open all switches and breakers in connection with this machine. The rubbing or sliding action between the parts has a tendency to clean them. If the operator from time to time inspects for loose connections and if copper contacts are used, filing or sandpapering contacts smooth will be quite adequate maintenance.

In the last couple of years, a silver alloy contact has been developed and is now in extensive use. Oxidation on this metal has the advantage of causing a better conductivity than copper. These contact surfaces according to the manufacturer should never be sandpapered or filed.

One of the annoying things in control apparatus is the burning out of holding coils, if that type of control is used. This is often caused by poor contact or connections, but after the operator is sure that contacts and connections are all right, it is well to check up on the voltage rating of these coils. If for instance the coils are wound for a certain voltage and the operator finds that the voltage leading to the coils runs considerably higher, either the voltage should be reduced or if this is not practical, coils wound for a higher voltage should be ordered. Some pumps have time relay starters, designed to bring the motor up to speed without drawing excessive current from the line. These starters also act when shutting down a pump and they will not make contact again until the pump has come to rest. Care should be taken not to change this time limit relay as damage might result when pump would be started while it was still running in the opposite direction.

Where, for motor or line protection, fuses are used instead of overload relays, they should not be higher than motor ratings as given in the electric code. In some cases where fuses blow often, some operators have a habit of overloading the fuse, which can be done, when link elements or cartridge fuses are used. The best protective device is a thermal overload relay which is operated by temperature, and

will open when for a certain period a pre-determined temperature is reached. Overloading of fuses should never be practiced as it is sure to lead to trouble; it is comparable to screwing a safety valve down on a steam boiler; the protection has been destroyed. Take the fuse out of the clips from time to time, clean the end of the fuses and also the inside of the fuse clips, try to rotate them while in the clips, and you can almost tell in this manner, if they make sufficient contact.

Maintenance of Air Lift Machinery

In plants where air lifts are in use, the prime mover is the air compressor. Depending upon the depth of the well, either single stage or double stage compressors are used. It is necessary that the lubricators oiling the several moving parts be turned on before the machine is started. If a splash system of lubrication is used it is necessary only to ascertain that enough oil is in the crank case. Here again care should be taken to prevent an excess of oil for lubricating the cylinders. If over-lubricated, oil will be carried along by the air into the discharge pipe and air receiving tank. This may become dangerous and cause an explosion. A high grade air cylinder oil must be used and due to the heat of compression must have a high flash point. The cylinders of medium and large size compressors are water jacketed. Two stage compressors are also equipped with an intercooler. Be sure to turn on the water through the cylinder jacket and intercooler *before* starting. Care should be taken to keep suction and discharge valves tight. If leaking valves are present, the capacity of the compressor will fall off rapidly and the temperature of the air discharged will increase due to recirculation of air in the cylinder. Be sure that the air receiver is kept free from water and oil and that the safety valve is in good operating condition.

A good operator is not only a man who can be depended upon to keep his plant ready for operation when needed, but also one who keeps down the cost. In order to keep down cost, he must keep records, just the same as a business. When taking charge of a plant, find what the guarantee of the manufacturer was at the time of installation, and what test results were obtained. Make an entry in a log book every day of the number of hours a certain piece of machinery is in operation. Keep a record of the different materials used and the hours of service this material has given you. Keep a list of repair parts of the different machines, on which parts are liable

to break down, and keep necessary parts such as coils or contact fingers in stock; you never know when you need them in a hurry. Keep daily records of the head you are pumping against, the number of hours the pump is in operation, the total amount of water delivered and the kilowatt hours used during that period. You must keep a record of the water you deliver, and by comparing pumping head, water delivered and kilowatt hours used, you soon find out if your efficiency is maintained, or if you are going down grade. And above all keep your machinery and its surroundings clean. A clean plant as a rule speaks for itself and is sure to make a good impression upon visitors and your superiors.

A great deal more could be said about handling machinery, such as the care of belts, either leather, rubber or V drives. If you have belt-driven machinery, keep belts at proper tension to do the work. If too tight a strain is put upon bearings and shafts, a waste of power results. A good example is the chain on a bicycle, make it too tight and you pump your lungs out. Gears, if used to drive machines, should be in proper mesh, both as to depth and surface. The operator should obtain a lubricant that will stick to the metal and at the same time is not too tacky. Where speed reducers are necessary, they should be kept filled to the oil mark on the housing and with oil as recommended by the manufacturers. They should be drained from time to time and flushed either with kerosene or a very light oil.



Effect of Enlarging a Main at Point of Diversion Of a Branch Line

By Samuel A. Evans

THE purpose of this paper is to determine the increased discharge obtained by enlarging a pipe where another pipe branches therefrom, as shown on Fig. 2 below. An infinite number of hypothetical cases might be assumed, but it is believed that the illustrations here given will be ample for an engineer, who can then readily deduce with a fair degree of accuracy the results obtainable in any similar case he cares to formulate.

A hypothetical case may now be considered. Assume the conditions in Fig. 1. Two quantities were assumed as flowing from a reservoir; any others might have been chosen. Figure 1 shows the energy grades for 50 and 100 cu.ft. per sec. Line A is in a canyon and water flows through it from a reservoir for slightly more than 6,300 ft., at which point a branch line leads off at a 90-degree angle. The branch, Line B, is laid up a hill for about 1,900 ft. and then down a hill, giving a hump in the line at about Station 82 + 30. The sizes of the pipe lines are taken at 36 in. inside diameter with an enlargement at the junction to 42 in. inside diameter as shown on Fig. 2.

For a trial, 50 c.f.s. was assumed as Q in Line B and then the capacity of Line A was determined to give the aforementioned Q ; the Q in Line A was found to be 76 c.f.s. Flows in Line B from 10 to 50 c.f.s. by increments of 10 c.f.s. were assumed and the additional quantity obtained by enlargement determined. This increase is plotted in the lower curve of Fig. 2, quantities being plotted as abscissae and the ratio of increase as ordinates, an abstract decimal number. The upper curve shows the ratio (abstract number)

A paper contributed by Samuel A. Evans, Civil Engineer, Bureau of Water Works and Supply, Los Angeles.

of the quantity flowing in Line A to the quantity flowing in Line B. Both curves have the same abscissa. It can readily be seen from

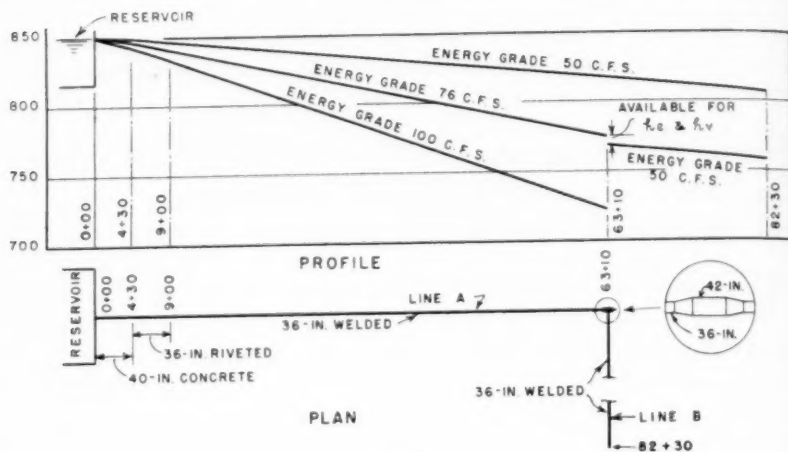


FIGURE 1

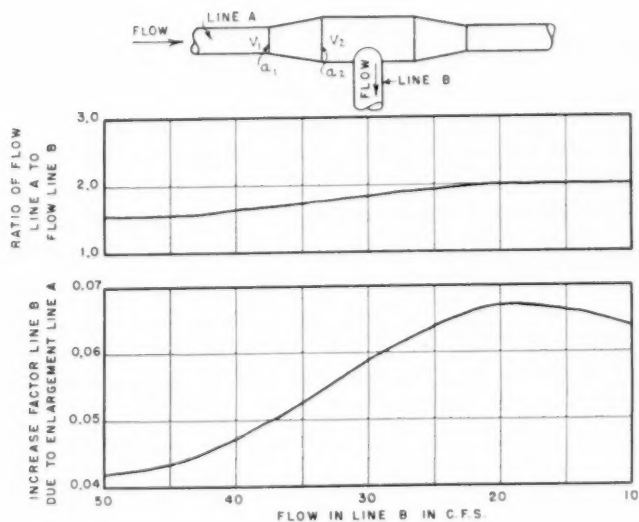


FIGURE 2

the upper curve of ratios that the increase factor increases due to the ratio, as might be expected. However, it will be noted from

this curve that the ratio is the same, namely 2, for a flow of 20 and 10 c.f.s. in Line B.

The ratio of flow curves would undoubtedly be a misnomer in practice in a water works system, since the flow in Line A would not in general increase in a faster ratio than Line B; therefore, the increase factor in the lower curve would not tend to increase as shown.

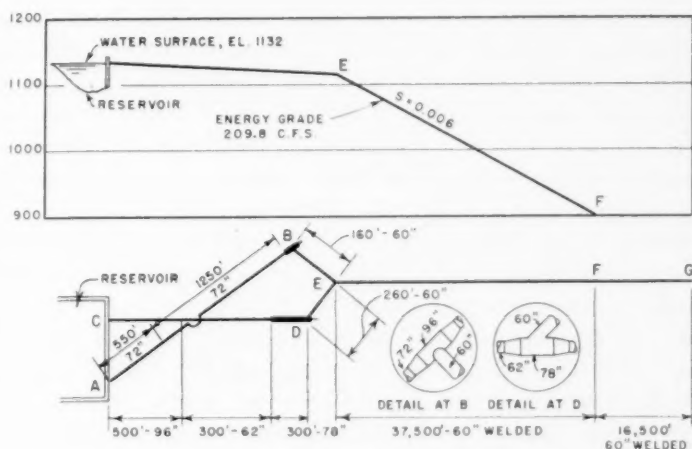


FIGURE 3

The method of computing the increase is:

The head gained, h_g , due to enlargement is determined from Formula 1.

$$h_g = \frac{v_1^2}{2g} - \left[\frac{v_2^2}{2g} + \left(1 - \frac{d_1^2}{d_2^2} \right) 0.1175 \frac{v_1^2}{2g} \right] \quad (1)^* \quad \text{Fig. 2.}$$

$$Q = \frac{0.463}{n} d^{\frac{8}{3}} s^{\frac{1}{2}} \quad (2)$$

Formula 2 was used in computing the quantities shown on Fig. 2. To determine the flow due to original energy plus h_g , the following formula (3) is used.

$$Q_1 = \frac{0.463}{n} d^{\frac{8}{3}} \left(S + \frac{h_g}{L} \right)^{\frac{1}{2}} \quad (3)$$

*0.1175 = sin of $\frac{1}{2}$ vertex angle of the upstream reducer—in this case $6^\circ 45'$. Other nomenclature is the same as generally employed in hydraulics.

Recourse to computations by a flow formula must be made to determine the flow due to enlargement, since the increment of flow is so small that it is not readily readable from hydraulic flow tables. L , the length from Station 63 + 10 to Station 82 + 30, gives a ratio of length to diameter of pipe of 640.

Another case will now be considered. Assume the conditions shown on Fig. 3, with 520 c.f.s. flowing from the reservoir, 220 c.f.s. in Line AB, and 300 c.f.s. in Line CD, with enlargements at B and D as shown by Details B and D respectively. The same nomenclature and formulas will be applied as previously. With quantities noted, $h_g = 0.61$ ft. at point B and 1.87 ft. at point D, S equal to 0.006 gives a flow of 209.8 c.f.s. from E to F. The proportional part of 1.87 ft. or 1.68 ft. is available at point D due to enlargement for increasing the flow in Line DEF. The remaining 0.21 is used in the line from F to G.

Substituting in Formula 3 the flow in DEF is increased from 209.8 c.f.s. to 210.59 c.f.s., an increase due to the enlargement of 0.79 c.f.s. or thirty-six hundredths of one per cent (0.36%). Assuming 300 c.f.s. in AB with 209.8 c.f.s. diverted at B, into BEF, $h_g = 1.16$ ft. at B. With the same method as previously used the flow in BEF is increased from 209.8 c.f.s. to 210.29 c.f.s., an increase due to enlargement of 0.49 c.f.s. or twenty-three hundredths of one per cent (0.23%). Smaller quantities were not computed as the line will follow the same course as in the first case, as shown for a number of varying quantities. In this case the gain is much smaller; in the first case the ratio of length to diameter equals 640; in this case it is 37,500 to 5 or 7,500.

In case of a short branch pipe line there might be some advantage in enlarging a portion of the supply main at the junction. Obviously there is an increase in discharge due to such enlargement, and the cost might be justified in case of a short line; however, the foregoing amply demonstrates the fallacy of spending the money in case of a long pipe line. After studying the cases outlined, the engineer will wonder whether "the game is worth the candle"; evidently it is not.



Removal of Salts from Water

By R. F. Goudey

DURING the past eighteen months two new groups of filtering materials have appeared on the market which will greatly revolutionize water conditioning and water softening processes. The first group of products includes cation exchangers which are carbonaceous zeolites having the ability to remove calcium, magnesium, sodium and other positive ions as ordinary zeolites remove calcium and magnesium. These cation exchangers include Catex (International Filter Company); Zeo-Karb (Permutit Company); Nalcite A (National Aluminate Corporation); and Organolite (Ellis-Foster Company). Cation exchangers operating on a hydrogen cycle are regenerated with mineral acids just as sodium zeolites are regenerated with salt. Cation exchangers operating on a hydrogen cycle convert carbonates and bicarbonates to carbonic acid gas which on aeration are eliminated and therefore indirectly remove the negative ions of carbonate and bicarbonate. The second group of materials is composed of anion exchangers which on taking water passing through a hydrogen cycle cation exchanger have the ability to remove carbonates, bicarbonates, sulfates, chlorides and nitrates and other negative ions. These materials include Nalcite B, National Aluminate Corporation; Anex, International Filter Company; and De-Acidite, The Permutit Company. Anion exchangers are regenerated with sodium hydroxide as ordinary zeolites are regenerated with salt. It is now possible on a large scale to remove salt (sodium chloride) from water which up to a few years ago was considered impossible save by distillation or the prohibitively costly precipitation with soluble platinum compounds.

The purpose of this paper is: first, to give greater publicity to this

A paper presented on October 26, 1939, at the California Section Meeting at San Francisco, by R. F. Goudey, Sanitary Engineer, Bureau of Water Works and Supply, Los Angeles.

great and important milestone in water purification history; second, to record a study of removal of boron, fluoride and other elements usually present in water in small quantities; and third, to point out some of its applications and limitations. Laboratory work was confined to a study of interchanges with sufficient investigation to determine broad economies in treatment. There was no attempt made to compare one material with another, to formulate specifications, or determine accurate capital and operation costs.

The first article which came to the author's attention on this subject was one by Burrell (1). In addition to a complete bibliography on the subject this article brought out the following points:

1. Absorption of cations by soils was observed by Way in 1850.
2. The use of zeolites commenced in 1906.
3. Humates were first used to soften water in 1931.
4. Humates were modified to increase base-exchange capacity with less coloring of the effluent by the addition of sodium, aluminum and chromium salts.
5. The first truly synthetic base-exchange material was produced by Adams and Holmes in 1935 in the form of synthetic resins prepared from polyhydric phenols and formaldehydes.
6. Cheaper synthetic exchangers with greater capacity and greater resistiveness have since been prepared from water soluble tannins made insoluble with sulfuric acid.

The second article which came to the attention of the author was by Bird (2). This article, after reviewing Burrell's work, adds:

1. The exchange by humates in the phenolic materials was due to the presence of the carboxyl group.
2. The exchange in tannin types of materials was due to sulfonic groups.
3. Filtration through some of these materials imparts tastes, odors, and soluble organic substances.
4. Negative ions other than carbonate and bicarbonate can be removed by anion exchangers first described by Adams and Holmes in 1934.

5. The best anion exchangers are now produced from resins derived by condensing aromatic amines with aldehydes and acids or by halogenating suitable bodies by amination.

A third article on the subject, by Applebaum (3), summarizes results of a large amount of laboratory and commercial installation tests dealing with carbonaceous zeolites, proving conclusively that their use is rapidly becoming more and more practical. At the

present time a number of trade articles are appearing by manufacturers showing considerable progress in various industrial installations. Carbonaceous zeolite development is still in its infancy and continued caution in its application will be needed to make its progress certain and orderly.

Parallel with this development considerable work has been done on the removal of fluorides from water such as:

1. The use of activated aluminum reported by Boruff (4), where a dose of 10 grains per gallon reduced fluorides from 6.2 to less than 1.0 p.p.m.

2. Removal by adsorption in the precipitation with excess lime by Scott and others (5), where fluoride of 3.0 p.p.m. was reduced to less than 1 p.p.m.

3. Use of tricalcium phosphate, magnesium oxide, or magnesium hydroxide by Elvove (6).

4. Defluorite which is a mixture of phosphoric acid and lime regenerated with 1 per cent sodium hydroxide followed by acidification with hydrochloric acid.

A number of household filters have been placed on the market using filtering medium to remove excess fluoride with varying degrees of success. This paper, however, is more concerned with the removal of positive and negative ions by exchangers rather than the removal by adsorption or precipitation.

There is some tendency to refer to both positive and negative ion exchangers as organolites or carbonaceous zeolites. There is also a tendency to speak of the positive ion removers as cation exchangers and negative ion removers as anion exchangers. For the purpose of this paper the term "siliceous zeolites" refers to ordinary zeolites which exchange sodium for calcium and magnesium. The term "cation exchangers" refers to organic zeolites whether operated on a hydrogen or sodium basis removing positive ions as well as carbonates and bicarbonates when operated on a hydrogen cycle and subsequently aerated. The term "anion exchangers" will refer to those which have the ability to remove negative ions such as carbonates, bicarbonates, sulfates, chlorides and others.

An interesting experiment was that of passing 90 gal. of Los Angeles aqueduct water through 277 grams of a cation exchanger in a small filter $1\frac{1}{8}$ in. in diameter with the media 12 in. deep and operated at a rate of 3.0 gal. per sq.ft. per min. Table 1 indicates points on curves plotted from 30 analyses each of calcium, magnesium, sodium and pH at different stages of the process.

The sequence of exchanges is indicated in Fig. 1. In general, calcium, magnesium, sodium and other positive ions are immediately exchanged for hydrogen and the water is made acid. As soon as the hydrogen supply is exhausted the filter operates on a sodium cycle and additional calcium and magnesium are exchanged for sodium.

TABLE 1

Progressive Cation Exchanges; Summary Mineral Analyses—Calcium, Magnesium and Sodium
(Results in p.p.m.)

FILTRATE THOUSAND GALLONS PER CU. FT.	CALCIUM	MAGNESIUM	SODIUM	pH
Raw 0	23	8	40	7.8
.2	0	0	0	3.0
.4	0	0	0	3.0
.6	0	0	4.0	3.0
.8	0	0	18.0	3.0
1.0	0	0	56.0	6.2
1.2	0	0	65.0	6.6
1.4	0	0	67.0	6.9
1.6	0	0	68.0	7.0
1.8	0	0	66.5	7.2
2.0	0	0	64.0	7.2
2.2	0	1.0	61.0	7.2
2.4	0	9.0	57.0	7.2
2.6	0	16.0	41.0	7.2
2.8	0	18.5	40.0	7.2
3.0	0	19.0	40.0	7.2
3.2	1.0	18.0	40.0	7.2
3.4	13.0	10.0	40.0	7.2
3.6	18.0	8.0	40.0	7.2
3.8	19.0	8.0	40.0	7.2
4.0	20.0	8.0	40.0	7.2
4.2	21.0	8.0	40.0	7.2
4.4	22.0	8.0	40.0	7.2
4.6	22.0	8.0	40.0	7.2
5.0	22.0	8.0	40.0	7.2

The sodium concentration is then nearly twice that of the original aqueduct water. When all the sodium in the filtering medium is displaced additional calcium is removed using magnesium as a replacing agent. On the exhaustion of the magnesium the medium has no further removing value. In this experiment the amount of

sodium and magnesium first removed does not correspond exactly with the amount later replacing other elements.

All waters filtered through cation exchangers operating on a hydrogen cycle produce an acid effluent. If only carbonates are present the pH will not drop below 4.0, but with a considerable amount of sulfates and chlorides present the pH may drop to 2.0. The acidity due to carbon dioxide may be removed by aeration but that produced from sulfates, chlorides, nitrates and other negative ions requires neutralization with alkali; removal of sulfates or chlorides; or mixing with untreated waters having alkalinity followed by aeration.

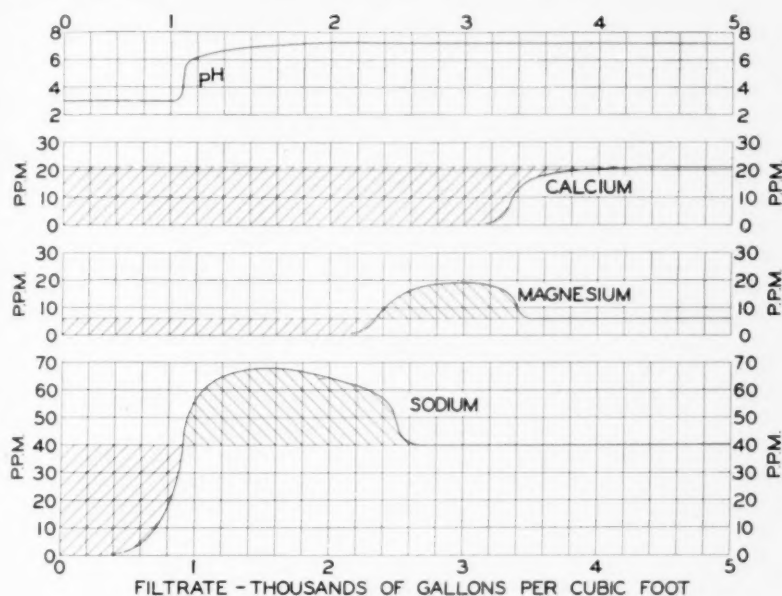


FIG. 1. Progressive Cation Exchanges with Carbonaceous Zeolite

The removal of calcium, magnesium, and sodium expressed as grains of calcium carbonate per cu.ft. averaged 8,550. The removal of calcium alone was 11,000 grains as calcium carbonate per cu.ft. of material. Since the type of material used has a rated capacity of 8,000 to 9,000 grains per cu.ft. it was seen that performance approached required specifications. The amount of acid used in regeneration when operating on a hydrogen cycle was equivalent to 2.5 lb. per cu.ft. of material used which is equivalent to a chemical

cost of \$20 per million gallons. When removing calcium only, less acid would be required.

Table 3 indicates the reactions for the three principal cycles for cation exchangers.

TABLE 2
Order of Cation Exchanges
(Results in p.p.m.)

THOUSAND GALLONS PER CU.FT.	CALCIUM	MAGNESIUM	SODIUM	pH
0 - .7	0	0	0-10	3.0
.7-2.2	0	0-1	10-68	3.0-7.2
2.2-3.2	0-1	1-19	68-40	7.2
3.2-3.6	1-18	19-8	40	7.2
3.6-4.4	18-22	8	40	7.2

TABLE 3
Typical Cation Exchange Reactions

HYDROGEN CYCLE	SODIUM CYCLE	MAGNESIUM CYCLE
$\begin{array}{c} \text{H}_2\text{Z} \\ + \\ \left. \begin{array}{l} \text{Ca} \\ \text{Mg} \end{array} \right\} \begin{array}{l} 1 \text{ CO}_3 \\ (\text{HCO}_3)_2 \\ 2 \text{ SO}_4 \end{array} \\ \text{Na}_2 \left\{ \begin{array}{l} 3 \text{ Cl}_2 \end{array} \right. \\ \downarrow \\ \left. \begin{array}{l} \text{Ca} \\ \text{Mg} \end{array} \right\} \text{Z} \\ \text{Na}_2 \left\{ \begin{array}{l} \end{array} \right. \\ + \\ (1) \text{H}_2\text{CO}_3 \\ (2) \text{H}_2\text{SO}_4 \\ (3) 2\text{HCl} \end{array}$	$\begin{array}{c} \text{Na}_2\text{Z} \\ + \\ \left. \begin{array}{l} \text{Ca} \\ \text{Mg} \end{array} \right\} \begin{array}{l} 1 \text{ CO}_3 \\ (\text{HCO}_3)_2 \\ 2 \text{ SO}_4 \end{array} \\ \text{Na}_2 \left\{ \begin{array}{l} 3 \text{ Cl}_2 \end{array} \right. \\ \downarrow \\ \left. \begin{array}{l} \text{Ca} \\ \text{Mg} \end{array} \right\} \text{Z} \\ + \\ (1) \text{Na}_2 \text{CO}_3 \\ (\text{HCO}_3)_2 \\ (2) \text{Na}_2\text{SO}_4 \\ (3) 2\text{NaCl} \end{array}$	$\begin{array}{c} \text{MgZ} \\ + \\ \left. \begin{array}{l} \text{Ca} \end{array} \right\} \begin{array}{l} 1 \text{ CO}_3 \\ (\text{HCO}_3)_2 \\ 2 \text{ SO}_4 \end{array} \\ \text{Na}_2 \left\{ \begin{array}{l} 3 \text{ Cl}_2 \end{array} \right. \\ \downarrow \\ \text{CaZ} \\ + \\ (1) \text{Mg}(\text{HCO}_3)_2 \\ (2) \text{MgSO}_4 \\ (3) \text{MgCl}_2 \end{array}$

The second part of the experiment was the passage of 100 gal. of cation filter effluent operated on a hydrogen cycle through 333 grams of anion exchanger in a small filter $1\frac{3}{8}$ in. in diameter with the media 8 in. deep and operated at from 1.63 to 3.5 gal. per sq.ft. per min. The volume of filtering medium was 0.012 cu.ft., giving a filtering rate of 2.45 gal. per cu.ft. per minute. Table 4 summarizes analyses

TABLE 4
*Progressive Anion Exchanges; Summary Mineral Analyses—Sulfates,
 Chlorides, and Alkalinity*
 (Results in p.p.m.)

FILTRATE THOUSAND GALLONS PER CU.FT.	SULFATES	CHLORIDES	ALKALINITY AS CALCIUM CARBONATE	pH
Raw 0	30	21	140	8.0
.2	0	1	8	8.6
.4	0	2	9	5.4
.6	0	1	8	5.1
.8	0	1	7	5.1
1.0	0	1	8	5.0
1.2	0	2	9	5.0
1.4	0	2	7	5.1
1.6	0	2	9	5.0
1.8	0	1	6	5.0
2.0	0	2	8	5.0
2.2	0	2	8	4.9
2.4	0	2	9	4.8
2.6	0	1	5	4.7
2.8	0	7	-6	4.0
3.0	0	12	-13	3.5
3.2	0	18	-20	3.3
3.4	0	24	-29	3.2
3.6	0	29	-37	3.1
3.8	0	31	-38	3.1
4.0	0	31	-38	3.1
4.2	0	31	-42	3.0
4.4	0	32	-43	3.0
4.6	0	35	-42	3.0
4.8	0	35	-40	3.0
5.0	0	34	-40	3.0
5.2	0	32	-39	3.0
5.4	0	32	-39	3.0
5.6	0	30	-38	3.0
5.8	0	31	-38	3.0
6.0	0	31	-38	3.0
6.2	0	29	-36	3.0
6.4	0	29	-37	3.0
6.6	0	32	-38	3.0
6.8	0	31	-40	3.0
7.0	0	33	-42	3.0
7.2	6	29	-40	3.0
7.4	8	28	-42	3.0
7.6	10	27	-44	3.0
7.8	10	28	-46	3.0
8.0	12	24	-44	3.0
8.2	12	25	-46	3.0
8.4	12	24	-48	3.0
8.5 .	20	24	-50	3.0

of every gallon filtered indicating progressive anion exchanges. The anion exchanger was used without aerating the cation exchanger effluent. The exchange sequence is further indicated in Fig. 2.

As soon as the residual sodium hydroxide used to regenerate the filter reacts with the residual carbon dioxide reaching it, the anion filter removes carbon dioxide, sulfates, chlorides and other ions except silica and boron. Fluorides were removed up to about 600 gal. of water filtered per cu.ft. after which fluorides were returned. Carbon dioxide removal was exhausted at about 500 gal. per cu.ft.

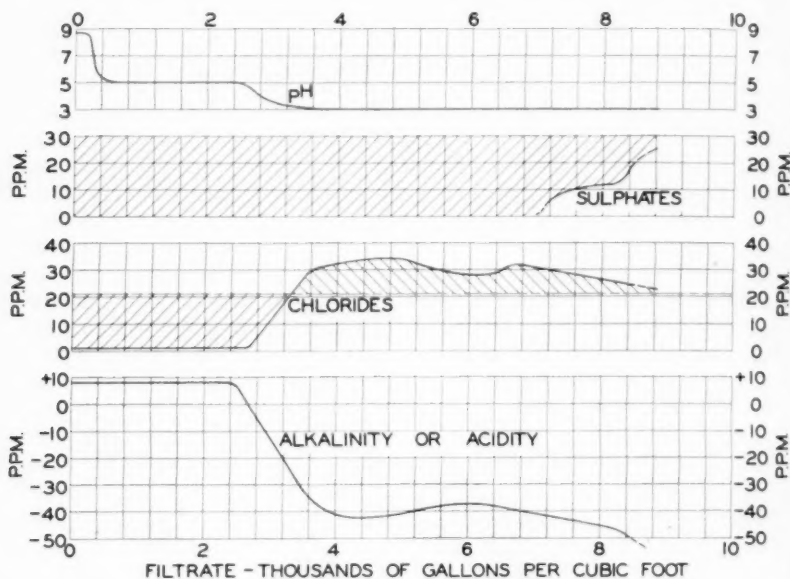


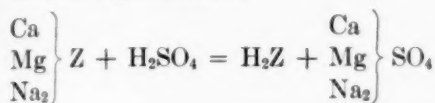
FIG. 2. Progressive Anion Exchanges with Carbonaceous Zeolite

Chlorides were removed up to 3,300 gal. per cu.ft. at which point chlorides were exchanged for sulfates. Sulfates were the last ion to saturate the anion exchanger. Apparently negative ions exchange for other ions as is the case of cation exchangers where sodium and magnesium replace calcium after hydrogen has been exhausted. The sequence in anion exchangers for the principal anions appears to be carbon dioxide, chlorides and sulfates respectively. The probable reaction of the anion exchange is according to that shown in Table 5.

Regeneration of both filters was in accordance with manufacturers'

recommendations which were found to be reliable. Reactions were as follows:

Cation regeneration:



Anion regeneration:

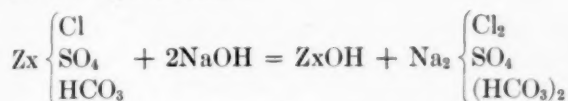


TABLE 5
Typical Anion Exchange Reactions

HYDROXYL CYCLE	CARBON DIOXIDE CYCLE	CHLORIDE CYCLE
Z(OH)_2	ZCO_3	ZCl_2
+	+	+
H_2CO_3	2HCl	H_2SO_4
or	+	↓
2HCl	H_2SO_4	ZCl_2
or	↓	+
H_2SO_4	$\text{Z} \left\{ \begin{array}{l} \text{Cl}_2 \\ \text{SO}_4 \end{array} \right.$	2HCl
↓	+	
$\text{Z} \left\{ \begin{array}{l} \text{CO}_3 \\ \text{Cl} \\ \text{SO}_4 \end{array} \right.$	H_2CO_3	
+		
$2\text{H}_2\text{O}$		

Removal of Elements

The removal of positive and negative ions by cation and anion exchangers is particularly astounding except for silica and boron. Fluorine appears to be partly removed (0.6 to 0.2 p.p.m.), but early in the cycle is replaced with higher than normal concentrations until that which had been previously removed is returned to the water. Boron does not appear to be affected.

Table 6 is a complete record of the mineral, and sanitary chemical examinations which show the accomplishment on the Los Angeles Aqueduct water passing both cation and anion exchangers.

Applications and Limitations

The question arises immediately—what do these processes cost? Using a figure of \$10,000 per million gallons installation cost for an ordinary pressure filter, the plant for treatment by cation exchangers

TABLE 6
Los Angeles Aqueduct Water; Removal by Cation and Anion Exchangers
(Results in p.p.m.)

	RAW	FINAL
Calcium.....	22.	0.
Magnesium.....	7.	0.
Sodium.....	40.	3.
Potassium.....	3.	.3
Total Hardness.....	84.	0.
Silica.....	27.	25.
Iron.....	.10	.00
Aluminum.....	.04	.01
Manganese.....	.005	.000
Molybdenum.....	.005	.000
Strontium.....	.5	.0
Bicarbonate Alkalinity.....	171.	8.
Chlorides.....	22.	1.
Sulfates.....	30.	0.
Phosphate.....	.18	.01
Nitrates.....	.00	.00
Fluorine.....	.60	.60
Boron.....	.62	.62
Ammonia.....	.000	.100
Nitrites.....	.001	.000
Oxygen Consumed.....	2.7	1.3
Taste.....	1.5	Palatable
Odor.....	2.0	None
Turbidity.....	3.	3.
Color.....	10.	7.
pH.....	8.0	5.1
Total Solids.....	235.0	35.
Specific Conductance ($K \times 10^3$).....	34.0	2.0

might cost about \$50,000 per million gallons capacity and plant for treatment by anion exchangers \$60,000 per million gallons for treatment of Los Angeles aqueduct water to the equivalent of distilled water. Both plants include special equipment for addition of acids

or alkalies and degassification or aeration. The operating cost for cation exchangers might be \$25 per million gallons capacity where 10,000 grains of salt expressed as calcium carbonate are removed for each 1,000 gallons of water treated, and \$20 for removal of negative ions equivalent to 4,800 grains per thousand gallons expressed as calcium carbonate. Complete treatment, therefore, for the Los Angeles aqueduct water might cost about \$110,000 per million gallons capacity for the installation and \$45 per million gallons for operation for the removal of all positive and negative ions. The chemical operation cost for complete treatment is equivalent to 3.3 cents per 100 cu.ft.

Because of the wide fluctuation in water analyses and the great number of possible combinations of treatment processes for any particular water, actual cost comparisons of specific processes must be made separately for each special case.

The cost of producing distilled water is approximately \$3,000 per million gallons which indicates that the new methods of treatment are more efficient than distillation for the removal of calcium, magnesium, sodium, alkalinity, sulfates, and chlorides. However, it is not necessary to remove all of the positive and negative ions from water and by mixing water treated to remove any particular ion with untreated water it is possible not only to soften water to any fixed standard but to remove undesirable ions.*

To remove 50 per cent of the hardness and sodium content of the Los Angeles aqueduct water would require complete treatment of half the water and subsequent mixing with the untreated half. This would involve a capital cost of \$55,000 per million gallons capacity and a chemical operating cost of \$12.50 per million gallons. In this instance it would not be necessary to use an anion exchanger and the mineral acidity in the portion of the water treated to zero hardness would be destroyed by the alkalinity in the untreated water mixed with it. This process would produce a water with sodium content nearer normal and would be a great saving to industries and owners of home hot water heaters. All traces of white precipitates on washed glassware and metal surfaces would be eliminated. Electrolysis and corrosion problems would be more readily controlled.

The advantages of softening high sodium and bicarbonate waters by hydrogen cycle cation exchangers are illustrated in the Los Angeles aqueduct supply, although it is not recommended that this be done. Table 7 includes a comparison of two methods of softening.

The first is treatment with excess lime and sodium zeolites with final mixing of one part raw and one part treated water to give a final hardness of 55 p.p.m. The second is filtration through an anion exchanger; aeration; and (likewise) mixing 50 per cent raw and treated waters. In the latter case the alkalinity of the raw water is used to neutralize the mineral acidity so that the final water will be alkaline. It is noted that the second method produces a water with

TABLE 7
Comparison of Ion Removals for Various Schemes of Treatment of Los Angeles Aqueduct Water
(Results in p.p.m.)

	LOS ANGELES AQUEDUCT RAW WATER	SOFTENED EXCESS LIME AND ZEOLITES TO ZERO HARDNESS	SOFTENED SODIUM ZEO- LITE TO ZERO	SOFTENED EXCESS LIME AND ZEOLITE WITH 1 TO 1 RAW WATER MIX	CARBONACEOUS ZEOLITE TO ZERO HARDNESS	CARBONACEOUS ZEOLITE AND AERATED	CARBONACEOUS ZEOLITE, AERATION AND 1 TO 1 RAW WATER
Carbonate Hardness.....	109	0	0	55	0	0	55
Permanent Hardness.....	0	0	0	0	0	0	0
Total Hardness.....	109	0	0	55	0	0	55
Calcium.....	29	0	0	15	0	0	15
Magnesium.....	9	0	0	5	0	0	5
Sodium.....	46	81	96	63	0	0	23
Hydrogen.....	—	—	—	—	4.19	1.65	—
Bicarbonates.....	155	114	155	135	155*	0	27
Sulfates.....	50	50	50	50	50	50	50
Chlorides.....	22	22	22	22	22	22	—
Total Solids.....	311	267	323	290	74	74	142
Per cent Sodium.....	48	100	100	70	0	0	48

* Present as free carbon dioxide.

one third of the sodium, one half of the total solids, and one sixth of the alkalinity for the same hardness reduction. The per cent sodium ratio is the same as the raw water and is suitable for irrigation, whereas the water softened by present standard method is obviously quite bad.

Waters with high permanent hardness such as the Colorado River water have insufficient alkalinity to neutralize mineral acidity when treated water is mixed with raw water so that alkali must be added to produce a neutral water. The latter being impractical, the re-

moval of some sulfate is desirable. Assuming a residual hardness of 100 p.p.m.; use of excess lime; zeolites; and mixing with 26 per cent of raw water, the sodium content of 80 per cent makes such water unsuited for irrigation purposes. Yet, if the water were softened by hydrogen zeolite on a hydrogen cycle; aerated; filtered through an anion exchanger to remove the sulfate content; and then mixed with 26 per cent of raw water to a final hardness of 100 p.p.m., the resultant sodium content would be 40 per cent. Other ratios may be used reducing the sodium content to 34 per cent with a final hardness of

TABLE 8

*Los Angeles Aqueduct Water Softened from 109 to 55 p.p.m.
(Results in p.p.m.)*

	SODIUM	ALKALINITY AS HCO_2	TOTAL SOLIDS	PER CENT SODIUM
Raw Water.....	46	155	311	48
Excess Lime and Zeolite.....	63	135	290	70
Zeolite Only.....	71	155	318	73
Cation Exchange.....	23	27	142	48

TABLE 9

*Colorado River Water Softened from 381 to 100 p.p.m.
(Results in p.p.m.)*

	SODIUM	ALKALINITY AS HCO_2	TOTAL SOLIDS	PER CENT SODIUM
Raw Water.....	90	166	788	34
Excess Lime and Zeolite.....	187	80	699	80
Zeolite Only.....	220	166	817	83
Cation and Anion Exchangers.....	23	0	195	34

100 p.p.m. It is apparent that by adjusting separate percentages treated by cation and anion exchangers and mixing with raw water, any desirable adjustment in any of the component parts can be obtained. Again this example is illustrative only and is not a definite recommendation on the problem of softening Colorado River water.

Cation exchangers are especially suited for softening waters of high alkalinity and for recarbonating lime softened waters. Water rendered low in alkalinity and total solids is desirable for carbonated beverages, dairies, canneries, textiles, dyeing, packing plants, bakeries, sugar refineries, ice plants, photography, paper mills, high pres-

sure boilers, and laundries. In washing glassware or metal surfaces prior to painting or plating water filtered through cation exchangers leaves no scale or noticeable deposit. Other special uses such as removal of magnesium for breweries can be taken care of by cation

TABLE 10
Comparison of Ion Removals for Various Schemes of Treatment of Colorado River Water
(Results in p.p.m.)

	COLORADO RIVER UNTREATED	SOFTENED EXCESS LIME AND ZEOLITE TO ZERO HARDNESS	SOFTENED ZEOLITE ZERO HARDNESS	SOFTENED EXCESS LIME + ZEOLITE WITH 26% MIX RAW WATER TO FINAL 100 P.P.M.	CARBONACEOUS ZEOLITE TO ZERO HARDNESS	CARBONACEOUS ZEOLITE + AERATION TO ZERO HARDNESS	CARBONACEOUS ZEOLITE + AERATION + 26% RAW WATER FOR RESIDUAL 100 P.P.M.	CARBONACEOUS ZEOLITE + AERATION + 26% RAW + AERATION + 232 P.P.M. NaOH	ANION EXCHANGE + AERATION + CATION EXCHANGE FOR 320 P.P.M. SULPHATES + 26% RAW WATER - 100 P.P.M. HARDNESS	8.1% THRU CATION + AERATION; 65.9% THRU CATION, AERATED + ANION; MIXED WITH 26% RAW WATER
Carbonate Hardness.....	137	0	0	65	0	0	0	0	0	0
Permanent Hardness.....	244	0	0	35	0	0	100	100	100	100
Total Hardness.....	381	0	0	100	0	0	100	100	100	100
Calcium.....	108	0	0	28	0	0	28	28	28	28
Magnesium.....	27	0	0	7	0	0	7	7	7	7
Sodium.....	90	221	265	187	0	0	23	157	23	23
Hydrogen.....	—	—	—	—	11.52	8.8	6.52	0	0	0
Bicarbonates.....	166	49	166	80	166*	0	43*	0	43	0
Sulfates.....	326	326	326	326	326	326	326	326	0	112
Chlorides.....	71	71	71	71	71	71	71	71	71	25
Total Solids.....	788	667	826	699	406	406	461	589	308	195
Per cent Sodium..	34	100	100	80	0	0	34	78	34	34

* Present as free carbon dioxide.

exchangers. In water softening with cation exchangers there is no sludge disposal problem as all waste products are brine solutions.

One disadvantage of cation exchangers is that they fail to remove silica but with aggressive waters they do not increase the silica content as sodium zeolites are reputed to do.

Anion exchangers are desirable in the removal of alkali salts in brackish waters in isolated desert and mountain areas where good natural waters are scarce. Waters high in permanent hardness are softened more cheaply by use of cation and anion exchangers than by any other known process. Waters with excessive sulfate and chloride contents may be reduced to acceptable limits.

Apparently the improved cation and anion exchangers do not deteriorate rapidly nor do they impart color, taste, or odor to domestic waters. They do require a reasonably clear water free of turbidities over 5 to 10 p.p.m. Rates of filtration appear to be high and backwashing must be lower than ordinary rates.

Summary

Cation and anion exchangers are reliable materials for use in municipal water softening, particularly where removal of alkali salts brings sodium sulfate or sodium chloride within Treasury Department limits or below the damaging limit for home irrigation use.

The cost of chemicals for softening bicarbonate waters with cation exchangers and high permanent hardness waters with both cation and anion exchangers appears to be within reason and particularly of advantage if lower sodium contents are justified.

Acknowledgment is extended to International Filter Co., National Aluminate Corporation, and the Ellis-Foster Company for samples of materials submitted; and to D. W. Graham, Chief Chemist and Bacteriologist, and to Philip Hoffman and Dorothy Margolin, Laboratory Technicians, Bureau of Water Works and Supply, Los Angeles, for helpful assistance.

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Discussion by R. B. Thieme.* The developments described by Goudey show definitely that hydrogen zeolite has a place in the water softening field. The problem of the water purification engineer now is to determine when and where hydrogen zeolite treatment is applicable. Water intended for softening with hydrogen zeolite must be clean, and free from turbidity, and suspended and organic matter. Any water not meeting these qualifications requires pre-sedimentation and filtration.

Goudey has brought out that when any raw water supply contains sodium carbonate in objectionable quantities, the hydrogen exchange treatment removes this salt in its entirety along with other bicarbonates that may be present and, except for distillation, hydrogen zeolite treatment is the only known method for such removal.

At the same time, where the predominant dissolved solids in the water supply are in the form of calcium and magnesium bicarbonates, lime treatment is far more desirable from the standpoint of initial cost and cost of operation, not to mention the elimination of the hazard in handling acids. This is particularly true in this section of the country where the raw water supply cost is an item because of pumping or delivery charges. Wash water for regeneration of hydrogen zeolite cannot be salvaged whereas the general practice in lime softening plants is to reclaim the filter backwash water.

Where a municipal water supply, in addition to containing temporary hardness, also contains much permanent or non-carbonate hardness, the cost of treating the entire community supply is usually prohibitive. For example, the Colorado River supply with its high sulfate and chloride content could not be treated by this latest softening method except at costs that are out of the question when compared with other available methods of treatment. It is interesting to note that the Metropolitan Water District engineers made an intensive study first of cation only and then of the combination of cation and anion softening treatment and rejected both because of the cost. Their decision to use lime treatment for the removal of calcium bicarbonate and subsequent treatment with sodium zeolite to remove residual hardness from the proper proportion of the lime treated water, in the writer's opinion, is really the most economical and efficient system of softening that could have been selected.

It is true that the hydrogen exchange process could be very seriously considered in treating Los Angeles aqueduct water because of

* International Filter Company, Los Angeles.

the sodium carbonate content of this water. This water, having its hardness all in the form of bicarbonates, could be treated with hydrogen zeolite to the point where a well-nigh perfect effluent could be obtained; but at the same time, a highly satisfactory water would result from the use of lime treatment at lower costs.

To date, the application of hydrogen zeolite to water softening problems has been confined to industrial operations where the quality of the treated water is the first consideration, and the cost of obtaining it secondary. This includes such industries as the carbonated beverage and ice making fields (when sodium carbonate is present in the raw water supply), film developing laboratories, textile plants, high-pressure boiler feed supplies, and numerous other industries where the requirements call for a water containing little or no alkalinity. As Goudey has pointed out, the cost of hydrogen zeolite treatment alone, or combined with anion removal, is far below that of distillation and such methods should replace expensive distilling installations in a great many places.

Where alkalinity reduction is the principal objective, selective or controlled exchange using hydrogen zeolite deserves careful consideration. In this selective exchange the metals of the bicarbonates are replaced by hydrogen, and the chlorides and sulfates are not converted. With this method of treatment, an alkaline effluent may be obtained and any desired portion of the bicarbonates removed, the amount being predetermined by the amount of acid used for regeneration. Generally speaking, a saving of from 25 to 40 per cent of acid is effected, which brings the cost of treatment to the point where it may compare favorably with alkalinity reduction by lime treatment.

Goudey mentions the regeneration of Defluorite, or Fluorex, which is used for the removal of fluorine compounds from water supplies, and refers to the use of 1 per cent sodium hydroxide followed by acidification with hydrochloric acid. Your attention may well be directed to the simpler regeneration method which has been developed and proved by the writer's principals. This consists of using carbon dioxide instead of hydrochloric acid. Not only does this newer regenerating method eliminate the hazard of handling acid but it results in a savings in the wash water required. This is almost always an important factor when considering the treatment of California, Nevada and Arizona supplies. Furthermore, hydrochloric acid regeneration of Fluorex resulted in approximately a 2

per cent loss of capacity of the mineral per regeneration and this loss is practically eliminated when carbon dioxide is used. In fact, with the latter system of regeneration, the only loss of mineral is through attrition which is negligible as in the case of zeolite minerals.

Discussion by Harry Burrell.* Goudey's paper is an important addition to the literature of *organic ion-exchange materials*, under which designation are included both cation and anion exchangers. It contains the first information to come to the writer's attention on the feasibility of the application of these materials to municipal water-treating problems. Heretofore most of the investigations have been of a general nature or else confined to some particular industrial application. Goudey's work, particularly that concerned with the Colorado River water situation, indicates that the organic cation exchangers and anion exchangers may provide the solution to some troublesome problems of water purification. Whether the results will warrant the cost of large scale treating of municipal water supplies depends in part at least on the response of public opinion, and for that reason it is difficult to predict the ultimate feasibility of the method. In a case of particular industrial application the problem can be analyzed more or less completely, and the usefulness stated in dollars and cents. This has been done in several cases and the importance of these materials has been demonstrated beyond doubt. In fact, the actual operation of several plants throughout the country is adequate proof that the use of the exchangers is not merely a laboratory proposition.

If treatment of public water supplies by organic ion-exchange materials comes into general use, it will probably be employed, as Goudey has indicated, either in the treatment of part of the water or else in combination with some other method of treatment.

In every new process a certain number of "bugs" are bound to occur and time is always required to iron out these difficulties. Most of these are eliminated by laboratory men as they arise. One of the objections to the use of this method that is frequently voiced and which cannot be solved in the laboratory is the danger of handling corrosive and caustic chemicals such as concentrated sulfuric acid and caustic soda. The only answer to this problem is training of personnel. Such substances can be and are handled with adequate

* Ellis-Foster Company, Montclair, N. J.

safety; but the fact that they are more or less new to field operators of water treating plants means that a hazard does exist at present and will continue until these men become familiar with the correct handling procedures.

Discussion by S. B. Applebaum.* Mr. Goudey is to be complimented on his interesting paper giving results of some laboratory tests with cation and anion removers, as well as pointing out the future possibilities for municipal and irrigation application of this type of water treatment. Manufacturers of water treatment zeolites and equipment will be stimulated to spend additional money in research work if the users' engineers create the demand for the solution of specific problems, as Mr. Goudey has done.

A demand was created for a non-siliceous zeolite which could withstand acid regeneration and which could then operate in the hydrogen cycle. Research work developed carbonaceous hydrogen zeolite which has already found application to a rather large extent in industry. Similarly, a demand is being created for anion removal and research work is developing products that will satisfactorily solve that problem.

The amount of pioneering research work and the date it was first started cannot be judged by the date of publications. Some manufacturers advisedly withhold publication until an invention has been thoroughly proved, not only in the laboratory but by pilot plants and later by large plants in the field. There were, however, two earlier papers which Mr. Goudey failed to mention.** These papers describe field installations made as early as 1936 and research work preceded that date by a considerable period. Such research work is exemplified by U. S. Patents Nos. 2,190,853, 2,191,059, 2,191,060 and 2,191,063 referring to carbonaceous zeolites.

The laboratory tests described by Mr. Goudey used depths of material of 12 in. in the case of the hydrogen zeolite and 8 in. in the case of the anion removal material. Quantitative conclusions based on such shallow depths must be used with caution. In the many

* Vice-President, The Permutit Company, New York.

** 1. APPLEBAUM, S. B., AND RILEY, RAY. Zeo-Karb H—A New Method of Conditioning Water to Remove Sodium Bicarbonate Chemically Instead of by Distillation. *Ind. Eng. Chem.*, **30**: 80 (1938).

2. TIGER, H. L. Carbonaceous Zeolites—An Advance in Boiler Feed-water Conditioning. *Trans. A.S.M.E.*, **60**: 315 (1938).

thousands of laboratory tests made in our laboratories, we have found a minimum depth of about 19 to 24 in. to be advisable in order to obtain consistent results in repetitive cycles. The paper does not disclose how many cycles were run in the case of the tests made.

The "progressive ion exchanges" that took place in both the hydrogen cycle and the anion removal cycle are interesting. However, industrial requirements are usually quite stringent, so that in actual practice a hydrogen zeolite unit is usually regenerated when the free mineral acidity of the effluent begins to decrease appreciably. For example, in the case of Table 1, the usual hydrogen zeolite unit would be regenerated after about one thousand gallons per cubic foot had passed through, because the table shows that the pH rises abruptly from 3.0 to 6.2 at this point. Industrial requirements usually call for a constant quality effluent to facilitate neutralization of the acid effluent and therefore enough acid is usually employed to regenerate the hydrogen zeolite, so that the free mineral acidity is quite constant throughout the run. It is true that for some purposes, such as municipal treatment when a constant alkalinity in the effluent may not be so essential, that less acid may be employed to regenerate the H_2Z (starvation treatment) and then the alkalinity will vary in the effluent and the cost of treatment will be lower. But thus far most of the industrial installations have been made to operate at a constant free mineral acidity. Consequently, the phenomenon which Mr. Goudey describes (progressive ion exchange) does not take place in the usual industrial runs of these softeners. They are regenerated before these phenomena are allowed to take place.

An analogous situation was known to exist in the case of sodium zeolite. It was known that ferrous iron and manganous manganese are removable by base exchange and that even after the sodium was used up, so that calcium and magnesium began to appear in the effluent, iron and manganese were still being removed. Some field installations were made to operate in this manner. But this progressive ion exchange was found to be unreliable as to quantitative consistency. Consequently, today where iron and manganese are removed by base exchange, the units are regenerated at the usual endpoint, i.e., when hardness begins to appear in the effluent.

In the case of the anion removers, reference is made to the removal of free carbon dioxide for a short initial part of the run. This is

usually not considered to be anion-removal. Probably the alkali used in the regeneration of the material has not been completely rinsed out and the first part of the run completes this rinsing and accounts for this carbon dioxide removal. It is therefore not customary to interpose a degasifier between the H_2Z and the anion-removal units. The carbon dioxide usually passes right through the anion-removal unit unchanged for the greater part of the run. In the "De-mineralizing" plants installed by us, to provide practically distilled water for industrial use, we therefore install the degasifier after the "De-acidite" anion removal unit. Furthermore, our research work has indicated that this anion removal is really not an exchange reaction, but is rather an acid-absorption phenomenon.

Mr. Goudey mentions the non-removal of silica and fluorides by these zeolites. The removal of these substances is another research problem that has been studied intensively for a number of years. Publication of completed and proven work is to be expected in the near future.



Sanitary Standards for Hotels

By G. E. Arnold

PUBLIC interest in the subject of hotel sanitation has been increasing for the past several years. The danger of cross-connections with other sources of water supply has been discussed in water works meetings for the past eight or ten years. In January, 1930, the surgeon-general of the U. S. Public Health Service issued an order to all state health officers directing them to refuse full certification to all water supplies where cross-connections existed between the public supply and any other source of water supply. This order referred only to cross-connections with other sources of water supply, there being no mention made of cross-connections with sewers or other sources of contamination. Following the outbreak of amebic dysentery in 1933, which resulted from cross-connections in two Chicago hotels, public interest in the subject of cross-connections and building sanitation became manifest. Since the Chicago affair of 1933, many organizations have adopted regulations regarding the sanitation in hotels where their conventions are held. The first of these organizations was the American Water Works Association. Since 1934, every convention hotel used by this association has had to submit to survey and comply with definite requirements before the hotel could be used for the convention. There have never been any definite specifications or standards established for hotel sanitation by this Association. The requirements to be met have been largely left to the judgment of the committee delegated to pass on the hotel. Last spring, the Board of Directors of the California Section instructed the writer to prepare a set of standards for convention hotels. These standards were prepared and forwarded to all members of the Board.

A paper presented on October 27, 1939, at the California Section Meeting at San Francisco, by G. E. Arnold, Chief Water Purification Engineer, San Francisco Water Department, Millbrae, Calif.

The purpose of this paper is to outline these standards as adopted for convention hotels with certain modifications to be applied to all hotels in general. For clarity in dealing with this rather complex subject, consideration should be given to several aspects: first, new hotels being designed; second, existing hotels being rebuilt; third, existing hotels undergoing extensive repairs or changes; and fourth, existing hotels where ordinary maintenance and repairs are conducted. Certain suggestions will be made which cannot be readily carried out in existing hotels without undue expense. It is the purpose to point out by these suggestions what should be done in the design of new hotels or in hotels undergoing extensive reconstruction or repairs. The question is a matter of economics and in all cases recommendations are made along the line of the best possible design features, but it must be remembered that these suggestions cannot always be met in existing buildings.

Water Supply

The water supply for any hotel must come from an unquestioned source. It is preferred that the supply be taken from the system serving the community. Wells or secondary sources of water supply may be used but they should be carefully surveyed for sanitary hazards. The water should be regularly examined by a competent laboratory and must meet the U. S. Treasury Department's standards for domestic water supply. Wells located in the basement of buildings should be adequately protected against flooding, contamination from machinery, or other sources, and should not be in the proximity of any sewers.

The water supply must be properly protected against contamination on the hotel premises. Storage tanks in the basement or lower levels of the hotel must be protected against entrance by rodents, should not be located under sewers or drain lines, should be provided with a tight cover; and any manholes or openings in the cover should be kept closed at all times except when actually in use for entrance. Drain lines from tanks should not be solidly connected to sewers but should have a free fall to a sump. Roof tanks should be covered and openings screened to prevent the entrance of insects and birds. All tanks should be provided with adequate drain lines for washing. All water for heating, cooling, pumping, or any other use should be otherwise handled in the manner which will prevent its becoming contaminated. Where a dual water system exists for

cooling, fire protection, or any other use, there must be no cross-connections between the secondary system and the domestic water supply. Double check valves may be permitted between dual systems if the check valves are regularly inspected and tested.

Where the water supply is treated in any way, such as, filtering, softening, treating for corrosion prevention, etc., treatment should be proper and adequate at all times and done under sanitary conditions. Only definitely approved chemicals should be used in treating water. A list of such chemicals and method of application has recently been adopted by the New York City Board of Health. Compliance with this New York regulation is recommended.*

Backwash or drain lines from tanks, filters, softeners, or other treatment equipment, must have a free fall to sewers or sumps. The lines must not be directly connected to sewers. Water used or reused, such as in ammonia compressors, recirculating pumps, air-conditioning, or other uses, should not be taken into the domestic system of the hotel except under conditions of superlative control. The refrigerant used in a cooling system should be non-toxic where cooling water is used. It is not advisable that water used for washing air in air-conditioning equipment be used in the domestic system unless it be properly treated by filtration and chlorination.

Water piping throughout any hotel should be adequate to take care of maximum flow conditions at all times. It must be properly designed, of good material and workmanship, and should be sufficiently equipped with bypasses and double lines to prevent discontinuance of water to any considerable portion of the hotel during repair work on the piping. Where water is stored in roof tanks it should be discharged at the top of the tank with a free fall above the overflow line. Where toilets are flushometer type, water supply lines to toilets should be in separate lines from those serving bathtubs, wash basins, drinking fountains, or other fixtures. If toilets are not supplied from separate lines, the piping must be of adequate size to take care of the maximum flow conditions which would occur should all fixtures be running wide open and all toilets on a line flushed at the same instant. Some plumbing codes specify the number of flushometer toilets which are permitted on any size piping at a given pressure and also specify the number which may be served through any given size meter. Ordinary maximum operating conditions must not create a

* See Jour. A.W.W.A., 31: 81 (1939) for article entitled "Regulatory Water Treatment in Buildings."

partial vacuum in any part of the water system. If pipe lines are not of sufficient capacity to supply water to all fixtures under these conditions, flushometer valves should be equipped with siphon breakers of an approved type. Because of the hazards encountered from the use of flushometer toilets, it is recommended that all such toilets be equipped with vacuum breakers. These may be readily installed on existing fixtures without undue expense.

If the hotel is equipped with an automatic sprinkler system and alarm, the bypass around the alarm for testing, as is required by some fire departments, should be equipped with check valves or discharge freely into an open sump.

Ice water for the hotel must be cooled and circulated under sanitary conditions. Ice water storage should be in a tight tank which allows no likelihood of contamination. The refrigerant used in any ice water system should be non-toxic.

The piping layout of any hotel should be regularly inspected and tested for leaks, stoppages, and other defects. If a water supply tends to be corrosive, tuberculation of the piping will materially reduce its capacity. Flow tests throughout the hotel should be made at intervals of not more than one year.

Plumbing fixtures present a hazardous condition in many instances. Old style bathtubs with bottom inlets should be done away with as rapidly as possible. Similarly, other antiquated fixtures of a hazardous nature should be eliminated, and new fixtures installed in buildings should be of a design which meets the requirements of the plumbing inspection division.

Sewerage System

The sewerage system in the hotel must be of adequate size, properly designed, and located, to take care of maximum flow conditions which may be encountered under any circumstances. Sewer piping should be of good quality and well constructed. Joints must be kept tight whether screw pipe or bell and spigot pipe is used. Clean-outs, flushing connections, unused branches, etc., must be capped or plugged with proper materials and must be kept tight. The use of wooden plugs, rags, tape, or other such materials for repairing or closing sewer pipes must not be permitted. The sewerage system, including grease traps and clean-outs, should be located so as to keep sanitary drainage away from kitchens, food storage area, dish-washing equipment, and ice manufacture or storage. Where such

conditions do not prevail, overhead sewer pipes, including grease traps and clean-outs, must be absolutely tight, and must be inspected frequently. Basement drainage should run to sumps which can be pumped or drained to sewers. Any equipment which drains to sumps should have a free fall from the discharge line above the overflow level of the sump. Any pumps, siphon ejectors, or other devices for draining sumps must have no domestic water supply connection to them unless they be protected by double check valves and test devices. Such test devices should be examined and approved at six-month intervals. Water lubrication of bearings in sewer pumps must not be permitted unless such water is delivered from an auxiliary tank which is filled by free fall from the domestic system.

Plumbing fixtures, such as bathtubs, toilets, wash bowls, etc., should be of good design and in good repair. Where fixtures are found that have inlet lines discharging below water level, it is recommended such fixtures be removed and replaced with modern fixtures. There must be no cross-connections of any nature between water and sewer pipe in any hotel. Where water connections are necessary to flush or clean sewer pipes such water must be delivered from an auxiliary tank into which the water discharges with a free fall. If increased pressure is necessary, water must be pumped. Where basement sumps receive sewage or any considerable volume of basement drainage which must be pumped into the street sewer, duplicate pumps should be provided. Hydraulic elevator waste should be free fall to sump or sewer.

Precautions for Handling Food

Storage and handling of food supplies should be done under sanitary conditions. Food storage rooms should be located away from overhead sewer lines, if possible, should be well-ventilated, and readily accessible for inspection. Food must be prepared and delivered under sanitary conditions avoiding storage in dark hallways or basements where dirt or other material may contaminate the food. Sinks and steam tables should be equipped with water inlets above the overflow line if the drain from the fixture discharges into a sewer. Kitchens, dishwashing rooms, and food storage rooms, should be located away from overhead sewers, if possible, but where overhead sewers do pass through these rooms such sewers must be absolutely tight and be inspected frequently. Garbage should be disposed of at least once daily and should be stored in a place that will neither

create offensive odors nor encourage the growth of garbage flies (*Drosophila*). Ice should be manufactured under sanitary conditions in rooms properly equipped for this purpose and employees of the hotel other than those whose work is directly connected with ice manufacture should not be permitted to enter the ice rooms. Water supply used for making ice should be of first-class quality, the freezing tanks should be protected from contamination, drainage lines should be provided with free fall to sumps or collecting sewers, and overhead sewer lines should not be permitted in the ice room. Ice storage should be in properly drained storage rooms and any ice which has been allowed to fall to the floor or has become dirty should not be used.

Swimming Pool Precautions

If the hotel is equipped with a swimming pool the domestic water supply for the hotel should be protected against cross-connection with the swimming pool either by free fall into lines or tanks supplying the pool or by double check valves. Recirculating pumps, filters, softeners, wash water, and other equipment for the swimming pool should have the same sanitary requirements as similar equipment for the hotel water supply. Swimming pool drainage should be by free fall to gravity sewer or removed with suitable pumps.

The hotel should be adequately ventilated in all quarters to provide sufficient fresh air for all purposes for which the rooms are intended. Where air-conditioning is employed, the air-conditioning units should be well maintained and any water used in connection with air-conditioning should be properly handled as indicated above.

Records and Personnel

There should be available a plan of the hotel showing the piping layout. This piping layout should be posted in an accessible place where it may be inspected at any time. Where such a plan is not available, it is recommended that one be prepared by the hotel management. Records should be kept of all hotel inspections and of any changes made in the piping or sanitary layout. Records of flow tests and other inspections of this type should be kept.

The personnel employed by the hotel should be competent and well-trained. Responsible positions should be given only to those who can fulfill the requirements of their positions. Periodic medical examination is recommended for all employees who have to deal

with food, ice, or water. No employee should be permitted to handle any food supplies who shows evidence of disease.

Summary

1. *Water Supply.* Dependable source, meets U. S. Treasury Department's standards, protected against contamination on premises, adequate volume and pressure.

2. *Sewerage System.* Good construction and condition. Adequate size, properly located, no cross-connections with water piping.

3. *Food.* Clean storage, good preparation facilities. Sanitary ice preparation and storage.

4. *Swimming Pools.* Clean, treated water, no cross-connections with domestic water piping. Water tested.

5. *Ventilation.* Adequate, no reuse of water from air conditioning equipment except after proper treatment.

6. *Inspections.* Use prepared form. Make two inspections before convention and daily inspections during convention. (Appended is a suggested form for hotel inspection.)

The above recommendations are outlined along the line of what would be considered ideal circumstances or conditions for a hotel. Consideration of the above specifications should be given in any new hotel or hotel being rebuilt. When changes in the piping are made in repair or maintenance work, or new fixtures installed, it is recommended that these changes incorporate the sanitary features outlined. Changes or alterations of the hotel piping by the hotel personnel should not be made unless a permit is obtained and the changes inspected by the plumbing division. It is felt that many hazardous conditions are introduced into the plumbing system by these subsequent changes made without permit or inspection. The writer's direct interest in this matter was established by the assignment to him of the duty of supervising the survey of hotels in the San Francisco metropolitan area. Six hundred and fifty-one hotels were examined in anticipation of the 1939 Fair. Of this number, more than 15 per cent contained one or more serious plumbing hazards, all of which were corrected before the fair opened. This illustrates the importance of this work and the prevalence of hazardous conditions within hotels.

DATA RECORD Sanitary and Cross-Connection Survey						Notice	
Premises			Location			Corrected	
Stories, Capacity, Nature of Business				Size & No. of Public Water Supply Services			
Auxiliary Water Handling Equipment							
	Filters	Softeners	Surge Tanks	Chemical Feeders	Boiler Makeup	Ammonia Cooling Water	Air Conditioning Water
Water Connection							
Waste Connection							
Remarks							
Tanks, Sumps, Sewers, and Miscellaneous							
Water Tanks—Cover, Waste and Type				Sumps—How Emptied, Water Connection			
Water Pressure Operated Injectors				Water Pumps—Dual Purpose			
Sewers—Number, Type, Condition, History				Fire System—Separate Make-up Cross-Connection			
Ammonia Blowoff to Sewer		Fountains,—Inlet, Waste			Hydraulic Elevator Connection		
Plumbing Fixtures							
	Lavatories		Kitchen & Bar			Miscellaneous	
	Toilets	Specials	Dish Wash Machines	Tanks	Water Cooled Grease Traps		
Type							
Number							
Supply							
Waste							
Remarks							
Wells or Other Supplies on Premises Use, pressure, quantity, quality, cross-connection				Public Water Supply Data Use, pressure, quality, treatment			
SUMMARY:							
				Date_____			
				By_____			

Discussion by Harry E. Jordan.* Mr. Arnold has done a real service by recording with definite emphasis the variety of hazards to health which can be found in the plumbing systems of hotels. It should be definitely understood that, except for certain details peculiar to a hotel, the same hazards can exist in office buildings, schools, hospitals, apartments, factories and other types of buildings. Among many articles in this Association's JOURNAL, the recent ones of Miller (31: 1702 (1938)), Fletcher (31: 969 (1939)), Lawrence (31: 977 (1939)) and McGonegal (31: 987 (1939)) cover the subject adequately and should be consulted by persons who have a substantial interest in the matter.

When the Board of Directors of the American Water Works Association in 1936, adopted its regulation concerning the sanitary survey of hotels in which its general conventions are held (JOURNAL, 28: 251 (1936)), its intention was primarily to protect the health of the Association's members. Its broader purpose was to promote the well being of the regular clientele of American hotels by having brought about the needed sanitary improvements in them. Unfortunately, few other associations have exhibited similar interest. Unfortunately also, the support to the idea received from public health officials is not as aggressive as could be desired. Regrettably, the safety of installed plumbing in large office buildings, hotels, hospitals, etc. has not kept in step with the advancing understanding of the hazards. This Association, through its Board of Directors, stands firmly upon its recorded intent to require sanitary surveys of the hotels in which its conventions are scheduled to be held. Its executive staff will continue to interpret the reports of surveys in the light of practical knowledge of the relative dangers involved and will not permit a hotel to be used as headquarters in which there exist known hazardous conditions of significant importance.

Mr. Arnold, in recording so definitely the various conditions in hotels which may be a source of danger, has done this Association, the American hotel industry and the general public, a definite service.

* Secretary, A. W. W. A.



Water Pollution by Petroleum Oils

By Mortimer M. Gibbons

THE importance of the petroleum industry in a modern industrial civilization with a high standard of living may be judged by the tremendous increase in the use of petroleum products since 1920. From 1920 to 1936 inclusive, consumption of motor fuel increased 345 per cent, gas and fuel oil 136 per cent, while the population increase is estimated at about 22 per cent (see Table 1). Most of this demand was for automotive and heating purposes, both industrial and residential. The distribution of petroleum products to a mass market has created a new problem for some public water supplies. This has resulted from the widespread installation of storage tanks for gasoline and heating oils, even in strictly residential communities. Waste incidental to distributing these products has affected the quality of drinking water under certain circumstances.

The gasoline service station with underground tanks, easily controlled pumps and company supervision is usually maintained in a clean condition and with little waste, although the potential hazard to water courses from spillage may be large. Oil and gasoline pipe lines crossing streams are usually well patrolled but there is danger of severe contamination from accidental breakage. The retail fuel yard, which often stores several kinds of fuel, has elevated tanks from which small truck tanks are loaded by gravity through a swing pipe. This type of storage station frequently wastes considerable oil to the ground by spillage, leakage from piping fixtures and tank overflow. Factories with oil storage tanks above ground are another source of possible waste. On occasion, usually after heavy rains in the winter, potable water supplies draining populated areas may be seriously affected by waste petroleum products. A disagreeable

A paper presented on October 21, 1939, at the New Jersey Section Meeting at Atlantic City, N. J., by Mortimer M. Gibbons, Sanitary Chemist, Newark, N. J.

oily taste and odor in the drinking water sometimes occurs and this causes widespread consumer complaint.

The rain which falls in the drainage area flushes out the waste oil and gasoline into streams and reservoirs. The turbulent flow intimately mixes the free flowing petroleum product with the water. As a result the storm water may contain suspended, emulsified and dissolved petroleum hydrocarbons. Volatile and low viscosity petroleum products such as gasoline and some heating oils present

TABLE 1
U. S. Domestic Consumption of Petroleum Products
(Thousands of Barrels)

YEAR	MOTOR FUEL	KEROSENE	GAS AND FUEL OIL	LUBRICANTS
1920	108,945	33,082	159,637	14,742
1925	232,745	39,969	264,177	20,581
1930	397,770	34,746	317,758	21,589
1935	434,810	47,645	337,494	19,661
1936	481,591	51,479	377,348	22,676
Increase, 1920-1936	372,646	18,397	217,711	8,934
Per cent increase	345	56	136	60

(Compiled from Statistical Bulletin of Am. Petroleum Institute, Vol. 18, No. 16, Mar. 27, 1937)

Population 1920.....	105,710,620
Estimated population January 1, 1937.....	128,877,000
Increase.....	23,166,380
Per cent increase.....	22

(Compiled from Bureau of Census Reports)

the greatest pollution hazard. They are widely distributed, flow freely in cold weather and inherently possess high odor.

Composition of Petroleum Oils

The composition and characteristics of petroleum oils have been described by Gurwitsch and Moore (1), as follows:

"The great variety and the unusually complex chemical composition of petroleum oils cause the detailed investigation of their constituents to be one of the most difficult problems of chemistry. The

separation and isolation in a chemically pure state of these substances is most difficult, and in many cases has, up to the present, been found impossible, not only because the most varied chemical groups, such as hydrocarbons, acids, phenols, bases, sulphur compounds, etc., are present, but also because so many isomeric and homologous compounds present themselves in each group. . . . All petroleum products are mixtures of various chemical individual substances. . . . Efforts are made, however, to limit so far as possible the inhomogeneity of each petroleum product, so that it shall consist only of such individual substances as are not too wide apart in physical properties. . . . Crude oils, as well as their distillates and residues, are but slightly soluble in water, though the latter when shaken up with petroleum products acquires their characteristic smell and taste, and the presence of dissolved organic substances may be proved by testing with potassium permanganate. . . . Further, the lower fractions are always more soluble than the higher fractions, and the difference in the solubility of various petroleum oils always becomes greater as we pass to the higher distillates."

The analytical determination of minute quantities of petroleum oils in water depends upon the use of a solvent to dissolve all or nearly all of the chemical constituents of the oil, the evaporation of the solvent and the weighing of the residue. *Standard Methods of Water Analysis* (1936) gives a method for a rough quantitative analysis using petroleum ether or high test gasoline as the solvent. The American Petroleum Institute (2) cites two recommended solvents (A) carbon-bisulfide-ether (chemically pure carbon bisulfide 55 per cent and ether 45 per cent); (B) carbon-tetrachloride-ether (carbon tetrachloride 45 per cent and ether 55 per cent).

These procedures answer the purpose for which they were designed, namely, the determination of oil in refinery effluents or boiler water feed but are of limited application to potable water supplies. This type of analytical determination gives the percentage by weight of all oily constituents, both low-boiling and high-boiling fractions. It can shed no light on the water solubility or vapor pressure of the petroleum fractions originally present. A measure of the latter properties is desirable for potable water supplies because the quantities involved in producing oily odors are so small. Consequently, it is necessary to measure the odor producing properties of different petroleum oils directly.

Odors in Water

The underlying principles for the determination of odors in water have been lucidly stated by Fair (3) from whom the following excerpts are quoted:

"Whatever the technique of measurement, it must be remembered in determining odor in water that an odorous substance contained in a liquid such as water must escape from the liquid into the air before it can be smelled. For perfect gases and with a fair degree of accuracy for other volatile substances—the escaping tendency or fugacity is measured by the vapor pressure of the gas. At low concentrations of odor producing substances, such as are generally encountered in water supplies, furthermore, the escaping tendency of a volatile substance is proportional to its concentration in the water. Hence it becomes possible to find the threshold value of such an odor either by diluting the water which contains the odorous substance or by diluting the atmosphere above the water after it has been saturated with the odor. Otherwise it would be incorrect to dilute the water. Time must naturally be allowed to elapse in either case to permit the odor in the air or gaseous phase to come into equilibrium with the odor in the water, or liquid phase, before testing for the odor . . . the fact should not be lost from view that the behavior of very high concentrations of odorous materials may not be in accordance with the assumption that the vapor pressure and hence the odor are proportionate to the concentration of the material. If there are visible oil films, for example, the water-dilution method, if carefully carried out, may yield information as to the concentration of the odor producing substances but not necessarily as to the intensity of odor produced by them in the undiluted sample. Generally speaking, however, the solubilities in water even of oils is relatively so great in comparison with the odor-producing concentrations encountered in water analysis that the assumption of a single phase system does not become incorrect."

Procedure in Measuring Odors of Petroleum Oils

The water-dilution method of odor measurement was used to obtain the threshold odor number (4)—the number of volumes of dilution of one sample volume to reach the just perceptible odor—of a group of common petroleum products, marketed under the same commercial name. The dilution requirement of each petroleum oil was de-

terminated by diluting it with odor free water, hot and cold, until the respective thresholds were reached. In adapting the water-dilution method for the odor determination of a group of sparingly soluble substances such as petroleum oils, it was necessary to meet certain conditions and to make certain assumptions. The initial concentration of oil in the primary oil-water mixture should be as low as consistent with its accurate measurement in order to favor solution of oil by the water and to keep any suspended oil portion as small as practicable. As cited above, the water-dilution method of odor measurement is only valid for very dilute solutions. The variation of the odor of the water soluble oil portion with concentration of oil may be seen in Table 5. The total volume of the primary oil-water mixture should be of convenient size so that uniform dispersion of any suspended oil can be obtained with a high speed laboratory stirrer before subsequent dilutions. It was assumed, in the absence of visible oil films or measurable turbidity in a Baylis turbidimeter, that at the threshold concentration the oil was dissolved in the water.

A very small volume of oil (0.05 c.c. or 0.10 c.c.) was transferred with a calibrated pipette into a large volume (4,000 c.c. or 5,000 c.c.) of odor-free water. This primary dilution was agitated by an electric stirrer at 1,000 r.p.m. for 15 min. Portions of the primary oil-water mixture were further diluted with odor-free water until the threshold—the just perceptible oily odor—was reached. A total volume of 250 c.c. of liquid in a 500 c.c. glass stoppered Erlenmeyer flask was used for each dilution (5). The hot odor dilutions were prepared with diluting water at 65°C., by shaking thoroughly, momentarily equalizing the pressure with atmospheric, and immersing in a water bath at this temperature for 15 minutes before smelling. The cold odor samples were diluted with cold water (20°C.), shaken, and kept at room temperature for 15 minutes before smelling. A cavity type glass nosepiece was used in smelling. A blank of odor-free water was sniffed before smelling each flask. Increments of 25 per cent of the primary dilution were used in making up subsequent dilutions. The threshold dilution was examined in a Baylis turbidimeter for measurable turbidity.

The procedure outlined has several limitations. It is possible that the hot threshold odor number of the more volatile petroleum fractions may be low due to escape of gases when the pressure in the dilution flask is momentarily equalized with atmospheric. The measurement of small volumes of the more viscous petroleum oils is difficult.

The difficulty of obtaining uniform dispersion of oil in the primary oil-water mixture increases with the viscosity of the petroleum fraction. There is a tendency for a portion of the viscous oils to adhere to the sides of the container. However, it is believed that this procedure, although not theoretically perfect, will give a fair estimation of the odor concentration of gasoline and heating oils. For the more viscous high-boiling petroleum fractions such as lubricating oil, the odor concentration can only be approximated because visible oil globules may be present at the threshold dilution. In view of the precision of odor measurement in general, these odor data may have considerable practical value in water supply treatment.

TABLE 2
Dilution Requirements of Petroleum Products
(Volumes of Odor-Free Water to Reach Threshold)

PETROLEUM PRODUCT	THRESHOLD ODOR NUMBER	
	Hot Odor (65°C.)	Cold Odor (20°C.)
Gasoline	8,000,000	5,000,000
No. 1 Heating Oil	4,000,000	1,500,000
No. 2 Heating Oil	12,000,000	3,000,000
No. 4 Heating Oil	10,000,000	2,000,000
Bunker C. Fuel Oil	7,000,000	2,000,000
20 w Lubricating Oil	80,000	40,000

Petroleum Products tested were marketed under the same commercial brand.

Gasoline and Heating Oils were free from visible oil films and from measurable turbidity in Baylis turbidimeter at the threshold concentration.

Odor Variation Among Petroleum Products

It may be seen from Table 2 that some petroleum products are highly odorous. Gasoline, Nos. 1, 2, and 4 heating oils and Bunker C fuel oil required from 4,000,000 to 12,000,000 volumes dilution to reach the hot odor threshold. Lubricating oil needed 80,000 volumes dilution. The cold odor thresholds were reached with lower dilution for all the fractions, varying from 5,000,000 volumes dilution for gasoline to 40,000 volumes dilution for lubricating oil.

These data indicate the wide odor variation among different petroleum fractions. Gasoline and heating oils have high odor; high-boiling fractions such as lubricating oil have relatively low odor.

Gasoline and No. 2 heating oil have an odor concentration of the order of a hundred-fold greater than lubricating oil.

Several different commercial brands of No. 2 heating oil were tested to determine what variation in odor thresholds might be expected. The data in Table 3 indicate that dilution to reach the hot odor threshold varies from 4,000,000 to 15,000,000 volumes for the No. 2 heating oil samples. Dilution to reach the cold odor threshold varies from 600,000 to 3,000,000 volumes. The maximum variation within the group examined was only five-fold. It is not implied that these odor ranges will include all commercial brands but they are believed to be representative. The odor variation among the several brands reflects differences in crude oil sources and refining procedure.

TABLE 3
Variation in Dilution Requirements of Several Commercial Brands of No. 2 Heating Oil
(Volumes of Odor Free Water to Reach Threshold)

COMMERCIAL BRAND	THRESHOLD ODOR NUMBER	
	Hot Odor (65°C.)	Cold Odor (20°C.)
A-1	5,000,000	1,500,000
A-2	12,000,000	3,000,000
B	5,000,000	1,500,000
C	8,000,000	1,500,000
D	15,000,000	3,000,000
E	4,000,000	600,000
F	8,000,000	2,000,000

Heating Oils tested were products of large refiners.

Effect on Water Supply

The striking feature of the dilution requirements of the petroleum products, reported in Table 2, is the variation among the different fractions. The odor thresholds of gasoline and heating oils are sufficiently low that drainage from contaminated areas may cause serious difficulty to water purveyors obtaining supplies from populated watersheds. Drainage from gasoline service stations and heating oil storage yards may be particularly odorous. Lubricants have comparatively high odor thresholds and require fairly low dilution. Moreover, they are of high viscosity and do not flow freely. The extent of the odor variation among the different fractions ex-

plains why storm water flowing over paved roads on which lubricant drip from automobiles has been deposited may have little odor, whereas drainage from a few carelessly operated storage yards may contaminate a whole water supply. This matter of street wash entering public water supplies is occasionally cited by fuel yard operators to justify their more odorous drainage.

Effect of Open Storage

Some water supplies are stored in open reservoirs before use. The period of storage varies widely, ranging from a few hours to several months. The effect of weathering on gasoline and heating oil contaminated water in open reservoirs was simulated by storing such water in open beakers outdoors on a window ledge for several days. The data in Table 4 indicate that the odor of gasoline and heating oil contaminated water may persist for several days. The odor changes in quality after a few days, losing its distinctive gasoline or oily character and becoming musty. The musty odor appears to result from the weathering of petroleum oil contaminated water. Control samples of odor free water, exposed for several days both outdoors and indoors, acquired a slight aromatic odor from atmospheric pollution but not a musty odor. This has interesting implications for water supplies. Few supplies are sufficiently contaminated to have a gasoline or oily odor. Many supplies have a musty odor of indefinable source. Possibly a portion of the musty odors may be due to petroleum contaminated drainage.

There is also a decrease in the concentration of odor with storage, as shown in Table 4. The time required for odor reduction will depend upon several factors such as weather conditions, organic content of the water and that bio-chemical change in water bodies often called natural purification. It is evident that open storage is beneficial in reducing odor arising from contamination with petroleum products. However, where the storage is brief or the contamination severe, objectionable odors may persist for several days, particularly in the winter months.

Effect of Coagulation and Sand Filtration

The value of alum coagulation and sand filtration in reducing the odors of petroleum oils in water appears to depend upon the concentration and physical state of the oil. Where the concentration of oil in water is low (1 p.p.m. or less) and the oil is probably largely

dissolved in the water, this treatment seems to be of limited value (see Table 5). The decrease in threshold odor number, upon filtration, of low oil concentration mixtures may be due to removal of suspended oil or absorption of dissolved oil or both. As the con-

TABLE 4
Effect of Outdoor Storage on Odor of Contaminated Water

SAMPLE	OUTDOOR STORAGE DAYS	WATER TEMP. DEG. C.	HOT ODOR (65°C.)	
			Quality	Threshold Odor Number
10 p.p.m. by volume Gasoline in Water*	Start	21.1	Gasoline	25
	2	18.9	"	25
	3	21.1	Musty chem.	25
	7	11.7	" "	15
	16	21.7	Musty	12
Filtrate of Above Gasoline Water Mixture†	Start	21.1	Gasoline	15
	2	18.9	"	15
	3	21.1	Musty chem.	12
	7	11.7	" "	10
	16	21.7	Musty	10
10 p.p.m. by volume No. 2 Heating Oil in Water*	Start	22.8	Oily	100
	2	11.7	"	100
	4	13.9	Oily, musty	80
	6	16.7	" "	60
	11	20.6	Musty	10
Filtrate of Above No. 2 Heat- ing Oil-Water Mixture†	Start	21.7	Oily	40
	2	11.7	"	30
	4	13.9	Oily, musty	30
	6	16.7	" "	30
	11	20.6	Musty	5

* Odor free tap water.

† Liter water samples stirred at 85 r.p.m. for 1 hr. with alum dose of 1 grain per gal.; then filtered through sand bed of 24-inch depth, effective size 0.40 mm., at rate of 2 gal. per sq.ft. per min.

centration of oil in water increases and a larger portion is in a suspended or emulsified state, this treatment may be highly beneficial. In the latter instance, the alum coagulation and sand filtration remove suspended and emulsified oil and thus prevent subsequent solution of the oil by additional dilution water. Moreover, as indicated in

Table 5, the threshold odor number of the water soluble oil portion appears to decrease with increasing concentration of oil in the mixtures. This may be due to preferential solubility of less odorous chemical groups in the oil at the expense of the more odorous constituents. Consequently, the greatest value of coagulation and sand filtration is at the point of heavy oil contamination. At the water works intake, where the oil is usually dissolved in the water, filters may afford slight protection.

TABLE 5

Effect of Coagulation and Sand Filtration on No. 2 Heating Oil—Water Mixtures

CONCENTRATION OF NO. 2 HEATING OIL IN APPLIED OIL- WATER MIXTURES P.P.M. BY VOL.	HOT ODOR (65°C.), THRESHOLD ODOR NUMBER AFTER FILTRATION	
	Total Dil. Vol. to One Vol. Filtrate	Total Dil. Vol. to One Vol. Orig. Oil
10,000	800	80,000
1,000	300	300,000
100	80	800,000
10	40	4,000,000
1	8	8,000,000
0.2	2	10,000,000

NOTES: 1. Threshold odor number of No. 2 heating oil used—12,000,000.

2. Heating oil mixed with cold (20°C.) water for 15 min. at 1,000 r.p.m. Then 1 grain per gal. of alum was added and stirred for 1 hr. at 85 r.p.m. Mixture was then filtered through sand bed of 24-inch depth, eff. size 0.40 mm., at rate of 2 gal. per sq.ft. per min. Odor-free water used throughout.

3. Turbidity of all sand filtrates in Baylis turbidimeter was less than 0.1 p.p.m.

Removal of Oily Odor

Water supplies unprotected by storage or filters are especially susceptible to oily taste and odor. Aeration, chlorination and potassium permanganate treatment may reduce the oily odor. Aeration is most effective when the pollution is from volatile petroleum fractions. Chlorine should be used with caution and after careful tests because of the presence of unsaturated compounds in some of the petroleum fractions. Addition or substitution compounds formed by chlorine with some of the soluble hydrocarbons may increase the odor of the water. Data in Table 6 show the residual odor after treatment of oil contaminated water with varying doses of chlorine. The need for careful regulation of the dose is apparent. Where applicable, chlorine treatment gives cheap odor reduction. Po-

potassium permanganate may also give cheap odor reduction but an excess of the chemical may impart a bitter taste to the water. Where the pollution is severe, these chemicals may be unable to remove the oily odor completely. They are most effectively used prior to absorbents such as activated carbon and bleaching clay. Dodd (6)

TABLE 6
Removal of Oily Odor From Water

WATER TREATMENT	HOT ODOR (65°C.), THRESHOLD ODOR NUMBER	
	Before Treatment	After Treatment
Laboratory*		
Control-alum, cotton filtration†	30 oily	
10 p.p.m. activated carbon	30 "	4 oily
40 p.p.m. bleaching clay	30 "	15 "
0.5 p.p.m. potassium permanganate	30 "	17 "
1.0 p.p.m. potassium permanganate	30 "	17 "
0.5 p.p.m. chlorine (resid. Cl.—0)‡	30 "	20 chlor. org.
1.0 p.p.m. chlorine (resid. Cl.—0.03 p.p.m.)‡	30 "	40 chlor. org.
2.0 p.p.m. chlorine (resid. Cl.—0.20 p.p.m.)‡	30 "	20 chlor. oily
20.0 p.p.m. chlorine (resid. Cl.—15 p.p.m.)‡	30 "	10 chlor. org.
Municipal Water Plant		
Raw water§	40 oily, musty	
Alum, sand filtration	40 " "	30 oily, musty
Alum, 8 p.p.m. activated carbon	40 " "	8 " "
Alum, 8 p.p.m. activated carbon, sand filtration	40 " "	4 " "

* Liter water samples stirred at 85 r.p.m. for 1 hr. with 1 gr./gal. alum and treating chemical.

† 10 p.p.m. by volume No. 2 heating oil in odor-free tap water.

‡ Excess chlorine removed with sodium thiosulfate after 2-hour contact period and before odor test.

§ Oil contaminated raw water, mainly No. 2 heating oil.

has reported the successful use of pre-chlorination and bleaching clay for removing oily odors from water at Chester, Pa.

When filtration is available, absorption processes may be used with success. Activated carbon and bleaching clay remove the oily odor effectively, although the cost is greater than with chlorine or potassium permanganate. This is the safest type of treatment because close regulation of the absorbent dosage is less necessary than

with the other chemicals. The finely pulverized materials are usually mixed with the raw or coagulated water and the suspended portion of carbon or clay is removed on top of the sand filters. Activated carbon has a higher rate of adsorption for petroleum hydrocarbons in No. 2 heating oil than has bleaching clay but the cost per pound is greater. Choice of either material will be governed by the cheapest net odor reduction. In Table 6, typical results in removing the odor of No. 2 heating oil by these chemicals and absorbents are summarized. Odor determinations from a municipal water plant are also included. These tests were made during a period of oil contamination of river water which followed melting snow in the winter. The results are closely in line with the laboratory tests because the contamination was mainly from No. 2 heating oil.

Prevention of Pollution

The remedy for much of the refined petroleum oil contamination of water supplies appears to be education of the tank users, particularly in retail fuel yards and factories, where the hazard of petroleum waste may not be appreciated. The admirable bulletins of the American Petroleum Institute (2) for the disposal of wastes from refinery, service stations and bulk plants supply needed technical knowledge. The refineries with their technical personnel appear able to adapt sanitary engineering practice and equipment to their difficult problem. The model separator designed for oil refineries, recently reported by Hart (7), illustrates this tendency. For the scattered small storage tank owners many of the corrective measures, such as the installation of drip pans, proper handling of swing pipes and hose connections, and care in filling tanks, would actually save money. Even in difficult situations, the heaviest oil contaminated drainage can be segregated and filtered. With the co-operation of the storage tank users, the state health departments, and the provision of odor absorbents at water plants, the life of some water supplies, collected from populated areas, could be extended for many years.

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Calculating Most Probable Numbers in Coli-Aerogenes Analyses

By Richard Pomeroy

THE increasing use of the coli-aerogenes test to estimate the pollution of waters has been paralleled by the development of the mathematical theory for calculating "most probable numbers" from fermentation tube results. This development has been traced by J. K. Hoskins (1, 2, 3) and need not be reviewed here.

Various writers have published tables giving most probable numbers for the results which may be obtained with certain combinations of sample sizes. However, cases frequently arise which are not covered by even the most complete of these tables, for special situations often indicate the desirability of combinations other than those for which published data are available.

Recognizing the need of freeing sanitary laboratories from reliance exclusively on published tables of most probable numbers, Hoskins (1) simplified the procedure for calculating these numbers, and published tables of functions useful in the calculations. With the aid of his tables and procedure, most probable numbers can be calculated in any laboratory for any tube combination.

A study in the laboratory of the Los Angeles County Sanitation Districts of the mathematical procedure based on the probability theory revealed that the calculations could be further simplified. It is the purpose of this article to present simplified formulas for solving these probability problems.

The probability function, as pointed out by previous writers (1, 4), may be expressed as

$$y = \frac{1}{a} [(1 - e^{-N_1\lambda})^p (e^{-N_1\lambda})^q] \cdot [(1 - e^{-N_2\lambda})^r (e^{-N_2\lambda})^s] [(1 - e^{-N_3\lambda})^t (e^{-N_3\lambda})^u] \dots$$

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where N_1, N_2, N_3 , etc. are the sizes, in cubic centimeters, of the portions examined,

p, r, t , etc. are the numbers of portions of respective sizes giving positive tests for coli-aerogenes organisms,

q, s, u , etc. are the numbers of portions of respective sizes giving negative results for coli-aerogenes organisms,

λ is the concentration of organisms per cubic centimeter,

y is the probability of occurrence of the particular result, if the concentration from which the sample was drawn was λ ,

e is the base of Napierian logarithms = 2.7182818,

a is a constant for any particular set of observations.

The most probable number (which hereinafter will be abbreviated M.P.N.) is the value of λ which causes the above probability function to have its maximum value.

Various cases will be considered in the problem of ascertaining suitable values of λ to fulfill the criterion of the M.P.N.

Case 1—Positive Tubes from One Sample Size Only

For the case that the positive tubes are found only from one sample size, which we will let be N_1 , the function reduces to

$$y = \frac{1}{a} (1 - e^{-N_1\lambda})^p (e^{-N_1\lambda q}) (e^{-N_2\lambda s}) (e^{-N_3\lambda u}) \dots$$

An exact solution for the maximum value of this function may be obtained by the standard procedure of equating the derivative to zero, as follows:

$$\begin{aligned} \frac{dy}{d\lambda} = 0 = \frac{1}{a} [& N p e^{-N_1\lambda} (1 - e^{-N_1\lambda})^{p-1} (e^{-N_1\lambda q}) (e^{-N_2\lambda s}) (e^{-N_3\lambda u}) \dots \\ & - N_1 q (1 - e^{-N_1\lambda})^p (e^{-N_1\lambda q}) (e^{-N_2\lambda s}) (e^{-N_3\lambda u}) \dots \\ & - N_2 s (1 - e^{-N_1\lambda})^p (e^{-N_1\lambda q}) (e^{-N_2\lambda s}) (e^{-N_3\lambda u}) \dots \\ & - N_3 u (1 - e^{-N_1\lambda})^p (e^{-N_1\lambda q}) (e^{-N_2\lambda s}) (e^{-N_3\lambda u}) \dots \text{etc.}] \end{aligned}$$

By removing factors from this equation it may be reduced to

$$N_1 p e^{-N_1\lambda} - (N_1 q + N_2 s + N_3 t \dots) (1 - e^{-N_1\lambda}) = 0$$

$$e^{-N_1\lambda} (N_1 p + N_1 q + N_2 s + N_3 u \dots) - (N_1 q + N_2 s + N_3 u \dots) = 0$$

$$N_1 \lambda = 2.303 \log \frac{N_1 p + N_1 q + N_2 s + N_3 u \dots}{N_1 q + N_2 s + N_3 u \dots}$$

This may be written

$$N_1\lambda = 2.303 \log \frac{A}{B}$$

where A is the total volume of all portions used to inoculate the tubes, and B is the total volume of all portions which did not give a positive result.

A similar expression was given by Greenwood and Yule (5) for the case that only one sample size was used, but it was not extended to this more general case. It should be noted that no restriction is placed upon the relative sizes of N_1 , N_2 , N_3 , etc. The positive tubes may appear from any one of the various sample sizes. The only restriction is that positive tubes must come from only one sample size; N_1 refers to this sample size.

Example: Assume the following analytical result:

Sample size.....	100 c.c.	10 c.c.	1.0 c.c.
Tubes set.....	2	5	2
Tubes positive.....	1	0	0

$$A = 252 \text{ c.c.} \quad B = 152 \text{ c.c.} \quad N_1 = 100 \text{ c.c.}$$

$$N_1\lambda = 2.303 \log \frac{252}{152} = 0.506.$$

Since N_1 is 100 c.c., the M.P.N. is 0.506 organisms per 100 c.c., or 0.00506 per c.c.

Example: Assume the following analytical results:

Sample size.....	1.0 c.c.	0.1 c.c.	0.01 c.c.
Tubes set.....	3	3	1
Tubes positive.....	0	1	0

$$A = 3.31 \text{ c.c.} \quad B = 3.21 \text{ c.c.} \quad N_1 = 0.1 \text{ c.c.}$$

$$N_1\lambda = 2.303 \log \frac{3.31}{3.21} = 2.303 \times 0.01332 = 0.03068.$$

Since $N_1 = 0.1$ c.c., $\lambda = 0.3068$; the M.P.N. is 30.68 (or 31) per 100 c.c.

Case 2—Positive Tubes from Two Sample Sizes

Many problems in which positive tubes appear from two sample sizes may be simplified and treated by the formula for Case 1. In

particular, if all of the tubes in the first* group are positive, and a majority in a subsequent group are positive, then the first group usually has an insignificant effect upon the final result and can be ignored.

A complete solution for the general Case 2 problem, comparable to that of Case 1, has not been found, but a simplified expression may be derived which can easily be solved by trial. The mathematical procedure is analogous to Case 1, and need not be presented in detail here. The resulting general formula is:

$$N_1\lambda = 2.303 \log \frac{A - N_2r - Ae^{-N_2\lambda}}{B - (A - N_1p)e^{-N_2\lambda}}$$

Here e is the base of Napierian logarithms; values of e^{-x} may be found in various handbooks, or the term $e^{-N_2\lambda}$ may be changed to $10^{-0.4343N_2\lambda}$. N_1 and N_2 are the volumes of the samples which showed positive results. The formula makes no restriction as to the relative values of the N 's; usually it is advantageous to let N_1 represent the larger volume.

The calculation of the M.P.N. with the aid of the above formula is accomplished by substituting trial values of λ in the right side of the equation until a value is found which approximately satisfies the equation.

Example: Assume the following analytical results:

Sample size.....	0.25 c.c.	0.05 c.c.
Tubes set.....	3	5
Tubes positive.....	3	1

$$A = 1.0 \text{ c.c.} \quad B = 0.20 \text{ c.c.} \quad N_1 = 0.25 \text{ c.c.} \quad p = 3$$

$$N_2 = 0.05 \text{ c.c.} \quad r = 1$$

In order to estimate an approximate value of λ suitable for a first trial value, we may note that 20 per cent of the 0.05-c.c. tubes are positive. This would indicate somewhat more than 0.2 organisms per sample. The initial group of three positive tubes would make

* "First," "Second," etc. are used here with the understanding that the groups of tubes are arranged in order from the largest portions to the smallest; the subscripts of the N 's may arbitrarily refer to any groups of tubes.

this value higher—it may be guessed to be 0.3 per 0.05 c.c., or 6 per c.c. Hence

$$N_1\lambda = 2.303 \log \frac{1.00 - 0.05 - 1.00e^{-0.3}}{0.20 - (1.00 - 0.75)e^{-0.3}}$$

Since $e^{-0.3}$ is found from tables to be 0.7408, this simplifies to

$$N_1\lambda = 2.303 \log \frac{0.95 - 0.7408}{0.20 - 0.1852} = 2.303 \log \frac{0.2092}{0.0148} = 2.65$$

$$\lambda = \frac{2.65}{0.25} = 10.6 \text{ per c.c.}$$

An important property of these equations must now be noted: *The true value of λ necessary to satisfy the equation always lies between the value assumed in the trial calculation, and the value which appears as a result of that calculation.* Hence in this case, the desired value of λ lies between 6 and 10.6. The calculation may now be repeated, using a trial λ of 8; the result of the trial calculation in this case comes out $\lambda = 8.62$. This result suggests $\lambda = 8.3$ for a third trial; the result in this case is $\lambda = 8.46$. It is now evident that the desired value of λ correct to two significant figures, is 8.4. Hence the M.P.N. is 8.4 per c.c. or 840 per 100 c.c.

Example: Assume the following analytical results:

Sample size.....	30 c.c.	10 c.c.	3 c.c.	1 c.c.	0.3 c.c.
Tubes set.....	3	3	3	3	3
Tubes positive...	2	0	1	0	0

$$A = 132.9 \text{ c.c.} \quad B = 69.9 \text{ c.c.} \quad N_1 = 30 \text{ c.c.} \quad N_2 = 3 \text{ c.c.}$$

$$p = 2 \quad r = 1$$

The M.P.N. may be expected from the above results to be in the neighborhood of 1 organism per 30 c.c. sample, or $\lambda =$ about 0.03. Using this as a trial value, $N_2\lambda = 0.09$, $e^{-0.09} = 0.9139$. The trial calculation is:

$$\begin{aligned} N_1\lambda &= 2.303 \log \frac{132.9 - 3.0 - 132.9 \times 0.9139}{69.9 - (132.9 - 60.0) \times 0.9139} \\ &= 2.303 \log \frac{8.443}{3.277} = 2.303 \log 2.75 = 0.945 \\ \lambda &= \frac{0.945}{30} = 0.0315 \end{aligned}$$

A repetition of the calculation using $\lambda = 0.031$ gives $\lambda = 0.0310$. Therefore the M.P.N. is 0.0310 per c.c., or 3.1 per 100 c.c.

Case 3—Positive Tubes from Three Sample Sizes

If the first group of tubes is entirely positive, and a majority of tubes are positive in one of the two subsequent groups which show positive tubes, then the first group may be ignored and the problem falls into Case 2. Hence Case 3 is required only in those cases where divided results are present in the first group, with positive tubes in two subsequent groups, or where a group of positive tubes is followed by two groups containing minorities of positive tubes. The formula which may be used to solve these problems is:

$$N_1\lambda = 2.303 \log \frac{A - N_2r - N_3t - (A - N_3t)e^{-N_2\lambda} - (A - N_2r)e^{-N_3\lambda} - Ae^{-(N_2+N_3)\lambda}}{B - (A - N_1p - N_3t)e^{-N_2\lambda} - (A - N_1p - N_2r)e^{-N_3\lambda} - (A - N_1p)e^{-(N_2+N_3)\lambda}}$$

This formula is rather cumbersome, and the calculations must be carried to several places in order to determine the differences between numbers of similar magnitude; hence this method offers little or no advantage over the procedure of Hoskins (2). However, answers are quite readily obtained with the aid of a calculating machine, and the formula may well find favor in many situations.

N_1 , N_2 , and N_3 refer to the sample sizes which showed positive tubes. No restriction is placed upon the relative sizes of the N 's. In using the formula it is usually best to let N_1 refer to the largest size which showed positive tubes.

Example: Assume the following analytical results:

Sample size . . .	10 c.c.	1.0 c.c.	0.1 c.c.	0.01 c.c.
Tubes set	4	4	4	4
Tubes positive.	3	2	1	0

$$A = 44.44 \quad B = 12.34 \quad N_1 = 10 \text{ c.c.} \quad N_2 = 1 \text{ c.c.} \quad N_3 = 0.1 \text{ c.c.}$$

$$p = 3 \quad r = 2 \quad t = 1$$

$$N_1\lambda = 2.303 \log \frac{42.34 - 44.34e^{-\lambda} - 42.44e^{-0.1\lambda} + 44.44e^{-1.1\lambda}}{12.34 - 14.34e^{-\lambda} - 12.44e^{-0.1\lambda} + 14.44e^{-1.1\lambda}}$$

A reasonable guess as to a value of λ to satisfy this equation might be 0.2 per c.c. If an attempt is made to substitute this value in the equation, the denominator becomes negative. This difficulty may be

overcome by using a larger λ . (In general, when either the numerator or denominator becomes negative in the solution of either Case 2 or Case 3 problems, a higher value of λ is required.) Hence try $\lambda = 0.5$; $e^{-\lambda} = 0.60653$; $e^{-0.1\lambda} = 0.95123$; $e^{-1.1\lambda} = 0.57695$.

Calculation of numerator:	42.34	=	42.3400	
	$-44.34e^{-\lambda}$	=		-26.8935
	$-42.44e^{-0.1\lambda}$	=		-40.3702
	$44.44e^{-1.1\lambda}$	=	25.6397	
	Totals		67.9797	-67.2637
			-67.2637	
	Net		0.7160	

Calculation of denominator:	12.34	=	12.3400	
	$-14.34e^{-\lambda}$	=		- 8.6976
	$-12.44e^{-0.1\lambda}$	=		-11.8333
	$14.44e^{-1.1\lambda}$	=	8.3312	
	Totals		20.6712	-20.5309
			-20.5309	
	Net		.1403	

$$N_1\lambda = 2.303 \log \frac{0.716}{0.140} = 2.303 \log 5.11 = 1.63$$

$$\lambda = 0.163$$

It is now evident that the desired value of λ is between 0.2 and 0.5. If the calculation is repeated using a trial value of $\lambda = 0.3$, the calculation gives $\lambda = 0.230$. A third trial with $\lambda = 0.27$ gives $\lambda = 0.267$. Hence the M.P.N. is 0.27 per c.c. or 27 per 100 c.c.

Higher Cases

Rarely will it occur that positive tubes will be found in four sample sizes, without the possibility of reducing the problem to a lower case. When one of these complicated cases does arise, it may best be solved by the procedure of Hoskins, rather than by a further extension of the method developed here.

Indeterminate Results

Occasionally a set of tubes comprising one analysis will be all positive, and even more commonly all tubes may be negative. Of course no "most probable number" can be calculated in these cases,

yet the data may provide information of value. If all tubes are positive, it may be stated that the concentration of organisms "probably exceeds" a certain value. A logical interpretation would indicate that the concentration probably exceeds the minimum value for which the observed result has a probability infinitesimally greater than 50 per cent.

In calculating the "probably exceeded" values in these cases, tubes other than the smallest sample size may be ignored for practical purposes. The probability that a group of p tubes, each inoculated with N c.c. of sample, will be entirely positive is $(1 - e^{-N\lambda})^p$. If this function is set equal to 50 per cent, and the equation is solved for $N\lambda$, we get

$$N\lambda = 2.303 \log \frac{1}{1 - (\frac{1}{2})^{1/p}}.$$

Values of $N\lambda$, correct to two significant figures, are shown in Table 1 for various values of p :

TABLE 1
Probable Concentration of Organisms when All Tubes are Positive

p NUMBER OF TUBES IN LAST GROUP EACH INOCULATED WITH N C.C.	$N\lambda$ PROBABLE CONCENTRATION OF ORGANISMS PER N C.C.
1	0.69+
2	1.2+
3	1.6+
4	1.8+
5	2.0+
6	2.2+
7	2.4+
8	2.5+
9	2.6+
10	2.7+

If all tubes are negative, the concentration of organisms is probably less than the maximum concentration for which the probability of the observed result is just greater than 50 per cent. The probability of an all-negative result is $e^{-A\lambda}$, where A is the total volume used. Setting this function equal to 50 per cent and solving gives

$$\lambda = \frac{0.693}{A}.$$

Thus if an analysis used two tubes inoculated with 10 c.c. each, two tubes with 1 c.c. each, and two tubes with 0.1 c.c. each, and if all

tubes showed negative results, it may be stated that the concentration of organisms was probably less than $0.693 \div 22.2$ per c.c., or 0.031 per c.c., or 3.1 per 100 c.c.

A statement that a sample probably contains less than 3.1 organisms per 100 c.c., or a report showing the M.P.N. per 100 cc. to be 3.1-, when the data are as above, assumes the absence of other data which would make a lower concentration probable. If repeated analyses of a water supply of uniform quality show only rare positive results, the average concentration of organisms will be seen to be much lower than the limit indicated by a single analysis. If the purpose of such analyses is to ascertain the average composition of the water, then all analyses may be considered as though they were portions of one original sample. But if the analyses are made to detect abnormal pollution, then it must be noted that an all-negative result on a particular sample only shows that the concentration of organisms is *probably* less than the figure indicated by a calculation such as the above. These considerations serve to emphasize again the necessity of inoculating with large enough quantities, if possible, to get a fair representation of positive tubes, or at least to use large enough quantities so that an all-negative result indicates pollution below the tolerable limit.

Summary

Application of suitable mathematical procedures to the calculation of "most probable numbers" in coli-aerogenes analyses leads to a simple solution in case the positive tubes come from only one sample size, and to equations which can be solved by trial in other cases.

An interpretation of indeterminate results is suggested.

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Determination of Small Amounts of Cyanide In Water

By J. E. Fasken

THE widespread use of cyanides, not only in the extraction of gold from its ores, but also in many other metallurgical and industrial processes, has resulted in tailings and effluents from these plants being discharged into nearby lakes or streams. This condition naturally raises the question of the possibility of sufficient cyanide finding its way into the diluting water to make it dangerous to human beings, animals or fish. One grain of hydrocyanic acid is generally considered to be a highly dangerous, if not a fatal dose, for an adult person, so that a very few parts per million of cyanide would render the water totally unfit for domestic use. Much smaller concentrations are poisonous to fish. Southgate (1) found that as little as 0.1 part per million of cyanide is toxic to fish, and the high mortality among them in certain rivers was attributable to this cause.

Each year since 1928 this laboratory has been called upon to test several samples of water for the presence of cyanide. At first difficulty was experienced in finding a method by means of which small amounts of cyanide in water could be quantitatively determined. The first determinations were done by a colorometric method developed by us, using as a basis the qualitative Prussian blue test as given by Griffin (2). This method after several improvements was found to give fairly good results but owing to some shortcomings, which will be discussed later, it was decided to conduct further experimental work with a view to obtaining a more satisfactory procedure. This was accomplished in the development of a ferric thiocyanate method which has been found to be quite satisfactory for the determination of as little as 0.01 mg. of cyanide in

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50 c.c. of water (0.2 part per million). Details will now be given of both the Prussian blue and the ferric thiocyanate methods as developed by us, together with some references to other methods and certain sources of error which may occur in the carrying out of these determinations.

Prussian Blue Method

Reagents:

1. A 3 per cent ferrous sulfate solution. Dissolve 3 grams of C. P. ferrous sulfate, $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, in distilled water and make up to 100 ml.
2. A 1 per cent ferric chloride solution. Dissolve 1 gram of C. P. ferric chloride, $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$, in distilled water and make up to 100 ml.
3. A 10 per cent sodium hydroxide solution. Dissolve 10 grams of C. P. sodium hydroxide in distilled water and make up to 100 ml.
4. A 10 per cent sulfuric acid. Add 10 ml. of C. P. sulfuric acid to 75 ml. of distilled water and when cool make up to 100 ml.
5. C. P. sodium cyanide.

Procedure:

One liter of the water to be tested is made slightly acid with sulfuric acid and distilled. The distillate is collected in 50-ml. Nessler tubes. To each 50 ml. of distillate 3 or 4 drops of freshly prepared 3 per cent ferrous sulfate solution and a drop of 1 per cent ferric chloride solution are added. After mixing there is added 10 per cent sodium hydroxide solution, drop by drop, until no further precipitation occurs. The tubes are then allowed to stand for a few minutes. Then 10 per cent sulfuric acid is added until the precipitate is dissolved after which the tubes are allowed to stand several hours for the blue color to develop. Standards are prepared containing known amounts of sodium cyanide, ranging from 0.5 to 2 mg. NaCn , in 50 ml. of distilled water to which has been added the reagents exactly as in the case of the distillate. The color in each Nessler tube of distillate is compared with the standard tubes and from the readings the cyanide content of the sample under test is determined.

Remarks:

It will be found that when 10 per cent of the sample has been distilled 90 to 95 per cent of the cyanide has passed over.

The much less poisonous, complex cyanide compounds, such as ferricyanides and thiocyanates are not determined by this method. The distillation from acid solution separates the simple cyanide from these compounds and to a slight degree decomposes ferro-cyanides yielding hydrocyanic acid.

In 1935 Childs and Ball (3) published a paper giving the results of an investigation of various methods for determining small amounts of cyanide in water. They include a Prussian blue method somewhat similar to the one developed by us. The chief differences consist of the addition of tartaric acid before distillation, the use of a much smaller volume of distillate and much weaker iron solutions. Using their procedure the color develops somewhat more rapidly but, while a color in tubes containing as little as 0.2 mg. CN is discernible, there is very little difference in the color finally attained in tubes having more than 0.5 mg. This is not surprising when it is found, on calculation, that the amount of ferrous iron added is, theoretically, sufficient to convert only slightly over 0.5 mg. of cyanide to ferro-cyanide. By increasing the concentration of both iron solutions from 0.1 per cent to 0.5 per cent a perceptible color develops in tubes containing only 0.1 mg. CN, while all the colors are much more intense. With this alteration this procedure can be used to determine amounts of cyanide from 0.1 mg. to 2.0 mg. in 10 ml. or a minimum of 1 p.p.m. in the original water.

The length of time required for the maximum color to develop as well as the flocculation and settling out of the Prussian blue in the Nessler tubes are shortcomings of the Prussian blue method.

Ferric Thiocyanate Method

On account of the difficulties with the Prussian blue test, as just explained, the thiocyanate reaction was studied as the basis of a more satisfactory method. After considerable work the following procedure was developed and was found to give satisfactory results.

Reagents:

1. Yellow ammonium sulfide. Ordinary laboratory reagent.
2. A 10 per cent sodium hydroxide solution. Dissolve 10 grams of C. P. sodium hydroxide in distilled water and make up to 100 ml.

3. A 5 per cent hydrochloric acid. Dilute concentrated C. P. hydrochloric acid with distilled water to 5 per cent HCl by weight.
4. A 10 per cent ferric chloride solution. Dissolve 10 grams of C. P. ferric chloride, $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$, in distilled water and make up to 100 ml.
5. Stock solution of potassium thiocyanate. Dissolve 4 grams of C. P. potassium thiocyanate in 1,000 ml. of distilled water. Determine the exact strength of the solution by titration with N/10 silver nitrate and dilute with distilled water so that 1.0 ml. contains 1.0 mg. of CN, (1 ml. N/10 silver nitrate = 2.6 mg. CN).
6. Diluted standard solution of potassium thiocyanate. Dilute 10 ml. of stock solution of potassium thiocyanate (reagent 5) with distilled water to 100 ml. One ml. of this solution is equivalent to 0.1 mg. CN.

Procedure:

Five hundred ml. of the water is acidified with 0.5 grams of tartaric acid, distilled, and 50 ml. of distillate collected. The whole distillate or an aliquot containing less than 2 mg. CN is placed in an evaporating dish and 0.2 ml. of 10 per cent sodium hydroxide and 0.5 ml. yellow ammonium sulfide added. The mixture is evaporated just to dryness on the water bath. If the yellow color should fade at any time during the evaporation, a further drop or two of yellow ammonium sulfide is added. The residue is taken up with 10 ml. distilled water, 1.0 ml. of 5 per cent hydrochloric acid added, and the mixture heated just to boiling. It is then allowed to stand for some hours for the sulfur to coagulate, after which it is filtered and washed into a 50-ml. Nessler tube till about 40 ml. have passed through. A series of standard tubes is prepared containing from 0.2 ml. to 20 ml. dilute standard potassium thiocyanate solution, corresponding to from 0.02 mg. to 2 mg. cyanide, each of which is diluted to about 40 ml. and acidified with 1.0 ml. of 5 per cent hydrochloric acid. Now 1 ml. 10 per cent ferric chloride solution is added to each of the tubes and the volume adjusted to 50 ml. After mixing the colors are matched immediately.

If the amount of cyanide is above 0.1 mg. the test may be simplified by making fewer standards and comparing with the nearest in a

colorimeter. While the color given by 0.01 mg. cyanide in 50 ml. is quite perceptible immediately after adding the ferric solution, it fades rather rapidly and comparison must be made at once. Hence this method is not recommended for amounts less than 0.05 mg. CN or 0.1 p.p.m. in the original water.

Remarks:

The ferric thiocyanate method is not recommended for amounts less than 0.05 mg. CN or 0.1 p.p.m. in the original water.

There is no appreciable loss of cyanide when the acid mixture is heated just to a boil and then allowed to stand until the sulfur coagulates. Using this technique a bright filtrate which remains clear on standing is obtained, whereas, if the acid mixture is only warmed gently it is difficult to get a clear filtrate.

The colors produced from cyanide by this procedure match almost exactly those produced by corresponding amounts of potassium thiocyanate. That is, the formation of thiocyanate from cyanide goes to completion. This is not the case with the Prussian blue method, since the colors produced there are always less intense than those produced from corresponding amounts of potassium ferrocyanide. This fact eliminates the necessity of preparing standard colors from cyanide solution with the consequent evaporation and filtration since a standard solution of potassium thiocyanate may be used for this purpose. However, if deemed necessary, standards may be prepared by treating known amounts of cyanide by the same procedure as in the determination.

Boyman (4) gives details for the colorimetric determination of cyanide using this thiocyanate reaction. Since this procedure does not distill off the hydrocyanic acid from the water it could not be used where there is an interfering substance such as ferrocyanide. Further, the Boyman method boils the strongly acid mixture for 15 minutes which results in a loss of some cyanide. Also, the much greater concentrations of acid and ferric iron give colors less intense than those produced by our procedure, thus rendering the method less sensitive.

Phenolphthalin Method

For concentrations of cyanide less than 0.1 p.p.m. the phenolphthalin method as described by Childs and Ball (3) has been

found dependable in most cases. The method depends on the oxidation of phenolphthalin in alkaline solution to phenolphthalein in the presence of a trace of cupric salt and a cyanide, thereby producing a red color. It is extremely sensitive, 0.0005 mg. CN in 10 ml. giving a distinct pink color. Unfortunately this color is not specific for cyanide since oxidizing agents such as chlorine and other halogens give a similar color.

Sources of Error

In any of these methods there are a number of causes of error, a few of which will be mentioned briefly.

1. *Oxidizing agents*: The presence of a strong oxidizing agent in the water may oxidize some of the cyanide to cyanate during distillation, and, if so, a low result will be obtained.

2. *Ferrocyanides*: As previously mentioned ferrocyanides are slowly decomposed on boiling with dilute acids, liberating hydrocyanic acid, and, if present, the result will be too high. Treatment of the water with excess of ferric iron before distillation will remove all but traces of ferrocyanide and the error will be relatively small when the cyanide content is over 0.1 p.p.m. There still remains, however, sufficient to give a distinct color when using the phenolphthalin test.

3. *Sulfides*: When sulfides are present, hydrogen sulfide will be found in the distillate. This will not affect the thiocyanate, but will interfere with phenolphthalin method by precipitating the copper. The sulfides may be removed by adding a slight excess of lead acetate and filtering off the lead sulfide before distillation.

4. *Halogens*: If free chlorine or other halogen is present in the water in sufficient quantity, it will be found in the distillate and will give a positive reaction in the phenolphthalin test. The presence of chlorine however, is easily detected by the ortho-tolidine test.

Summary

Three methods for determining small amounts of cyanide in water are discussed. Details of procedure are given for two of them.

The ferric thiocyanate method is recommended when the concentration of cyanide is above 0.1 p.p.m., and the phenolphthalin method where there is less than this amount.

A list of some possible sources of error is given.

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Porous Filter Bottoms at Flat Rock, Michigan

By Loran Stevens

ABOUT three years ago, a change in the supervision of the Flat Rock, Michigan, filter plant was made. It shortly became evident that much rehabilitation of the plant was necessary.

One rate of flow gage had never been installed, although called for in the drawings. The filter rate controllers and loss of head gages did not function. The main venturi meter was found to be under-registering by 20 per cent.

The filter units were in very bad condition. When wash water was applied to the filter, only that portion of the sand near the front of the filter was lifted. A mud shelf had formed at the rear of each unit. It extended about two feet out from the wall and the wash water had no effect in this area. Mud balls from $\frac{1}{2}$ to 3 in. in diameter were scattered throughout the sand. Activated carbon had colored these mud balls black. The lower sand layer was filled with the heavier mud balls.

Complaints of "black water" were frequent. It should be noted that this was not the result of applying carbon to a filter in good operating condition. It was, on the contrary, first due to the collection of carbon particles in the small mud pellets at the top of the sand. Ineffective wash had then allowed these pellets to grow into mud balls. As they grew in size, they sank into the sand, until finally they rested at the sand-gravel junction. Wash water rubbing them on the gravel abraded them enough to detach carbon-alum aggregates which, however, did not rise with the wash water and flow into the gutters. Flow of water under normal operating con-

A paper presented on September 22, 1939, at the Michigan Section Meeting at Lansing, Mich., by Loran Stevens, formerly Superintendent of the Flat Rock, Michigan, Plant of the Ford Motor Company.

ditions carried the particles along with the filtered water until they reached the consumers' taps with the resultant complaints.

It should be noted, at this point, that when occasion arose to clean out the clear well at a later date, about two tons of sand were removed from it. In other words, irregular washing had produced a wholesale disturbance of both the gravel and sand layers with the result that the gravel was not effective for the purposes for which it was installed; namely, (1) to support the sand, and (2) to distribute the wash water evenly.

Decision to Renovate Plant

A review of the situation led to the decision to rebuild the filters so that a high-rate wash could be applied. This required more freeboard. Lowering the sand surface by installation of porous plate underdrains and removal of the gravel seemed to be advisable.

Porous plates have been used as air diffusers in sewage disposal plants since 1916. They have been installed in several rapid sand filter plants. One unit at Grand Rapids, Michigan, was thus equipped several years ago. Inspection of this unit indicated that it was in the best condition of all the Grand Rapids filters. Incidentally, the fact that the original installation at this plant had included the old ridge-block filter bottom made the placing of porous plates a fairly simple matter.

Characteristics of the Plates

The specification upon which it was decided to purchase porous plates may be paraphrased as follows:

"The material to be furnished is commonly known as fused alumina plates. The size required is $11\frac{7}{8}$ in. square and $1\frac{1}{4}$ in. thick.

"The pore size shall average 0.4 mm. diameter and in no case shall exceed 1.0 mm.

"Each plate shall have such permeability that air applied at 2-inch pressure will pass through the plate at the rate of 50 cu.ft. per min. Plates, the permeability of which is not more than 10 per cent greater or less than 50 c.f.m., will be accepted."

(This specification for permeability is such as to provide a plate through which the head loss will range from 6 to 10 in. with flow at 20 gal. per sq.ft. per min.)

Porosity and permeability must not be confused. The term

"porosity" refers to free space within the plate, while the term "permeability" refers to the capacity of the plate to diffuse air or water through the free space. The limitations as to average and maximum size of opening govern evenness of distribution of flow, etc.

Certain tests of plates were made. Dr. G. E. Symons, of the Buffalo, New York, Sewage Disposal Plant, made certain tests of solubility of the plates under consideration. The results are shown in Table 1.

It may be noted that the materials used for the test were, with the exception of tap water, of a character not likely to affect the life of a porous plate when used as a filter bottom.

The solubility rate in tap water indicated a probable life of 175 years for the plate, given no other factor in depreciation than a solvent.

TABLE 1
Results of Tests at Buffalo, New York

SOLVENT	GROUND SAMPLE 9-12 GMS. LOSS	SOLID SAMPLE 36-50 GMS. LOSS
Distilled water.....	0.016 per cent	0.0045 per cent
Tap water.....	0.003 per cent	0.0016 per cent
21 per cent HCl.....	0.0645 per cent	0.026 per cent
21 per cent NH_4OH	0.023 per cent	0.000
48 per cent Chlorine water.....	-0.01 per cent	-0.0042 per cent
57.6 per cent Chlorine water.....	-0.0143 per cent	-0.0011 per cent

Certain loading tests were made—all with the plate supported at the four corners, with a total support surface of 2 sq.in.

With the load applied at the center of the plate, within the area of $\frac{3}{4}$ sq.in., the plate failed at 1,360 lb. load. With the load applied over a 72 sq.in. area about the center of the plate, the plate failed at 1,600 lb. load. The load capacity of each plate is assumed to be 2,000 lb. under distributed load conditions as found in a sand filter.

Sand was screened to pass a 30-mesh screen and remain upon a 40-mesh screen. A 3-inch layer of this material was placed on a plate and water allowed to flow downwards through the sand and the plate for 24 hours. Occasionally the plate was agitated. At the end of the period, the plate was broken. A few grains of sand were found to have penetrated $\frac{1}{4}$ in. within the plate but they were easily dislodged by a flow of tap water.

Installing the Plates

The filters had originally been built with 16-inch headers placed below the concrete floor of the unit. Three-inch riser pipes were installed on 12-inch centers. At the top of these risers, $2\frac{1}{2}$ -inch tees were

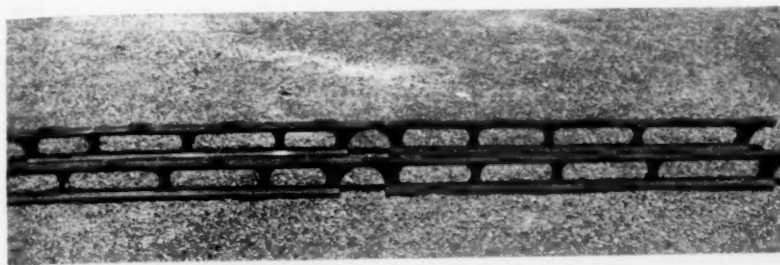


FIG. 1. Supports for Porous Plates where Underdrain Laterals are not used.

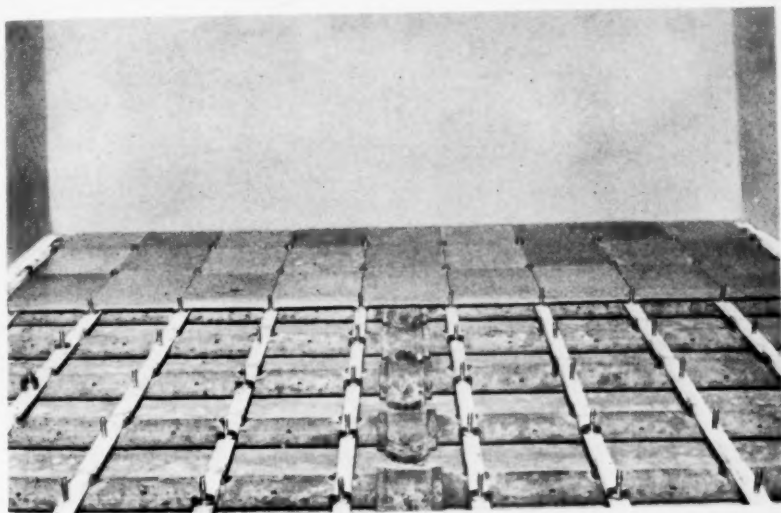


FIG. 2. Preliminary Step—Installing Porous Plates. Note holes drilled in side of laterals.

installed and the $2\frac{1}{2}$ -inch laterals fitted into them. The laterals were drilled at the bottom with $\frac{1}{2}$ -inch holes spaced on 6-inch centers.

At first it was intended to remove the laterals and the tees, leaving only the riser openings up through the floor from the header. This

plan involved the installation of a series of cast-iron supports upon which it was intended to place the porous plates.

Two of these supports are shown as a suggestion to any person who may wish to install porous plates in a filter and be unable to support them on the underdrain laterals (Fig. 1).

When the underdrains were exposed, it was found that they were in good order and could well be used to support the plates. They were drilled with additional $\frac{1}{2}$ -inch holes along the side on 6-inch centers (Fig. 2).

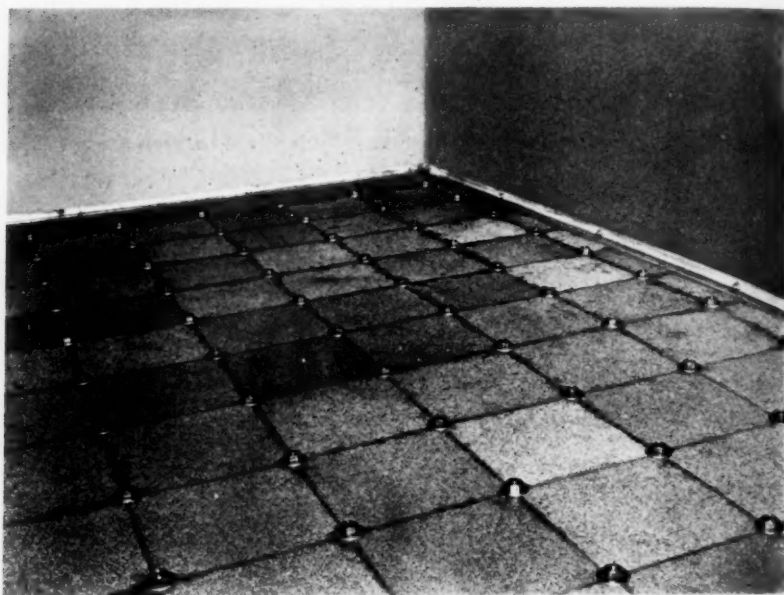


FIG. 3. Completed Filter Bottom—Porous Plate Installation

To these laterals were welded $1\frac{1}{2} \times \frac{1}{2}$ in. cadmium plated cold rolled steel bars with $\frac{1}{2}$ -inch tapped holes on 12-inch centers. Cadmium was used for plating these bars because of its faculty for healing over the welded spots. A cadmium plated angle iron was bolted to the walls all around the edge.

Phosphor, bronze bolts, washers and nuts were used to hold the plates. The washers were 2 in. wide by $\frac{1}{4}$ in. thick. The plates rest upon the washers so that very little of the plate area is lost as a

filtering medium. Not more than 8 sq.in. of the total 144 sq.in. of each plate is lost (Fig. 3).

It was decided to use a mixture of one part cement to two parts sand as a grout, rather than some plastic, to seal the joints between plates.

After installation the plates were kept wet for 48 hours and nothing further was done until the cement had hardened. Then the filter was washed to note wash water distribution. It was perfect. No part of the filter got wash water at the expense of some other part.

Then a 3-inch layer of torpedo sand (0.8 to 1.2 mm. diameter) was put directly on the plates as a factor of safety against possible pore plugging by grains. Atop that was placed a 30-inch layer of filter sand with an effective size of 0.52 mm. and a uniformity coefficient of 1.2. The freeboard had been increased 11 in., giving that much more room for sand expansion.

An entirely uniform expansion of sand and a higher wash water rate with perfect diffusion of wash water throughout the whole filter area has been obtained. From an expansion of approximately 40 per cent in a limited area in the center and toward the front of the filter unit the expansion has been increased to over 50 per cent— even distributed over the entire filter area.

The operating results have improved. The rate controllers and other items of equipment have been put into good condition. The clear well has been cleaned. The consumers' complaints have been greatly lessened.

Conclusion

Wherever operating conditions in a rapid sand filter are such as to prevent the proper washing of the entire area, the installation of porous plate underdrains should be considered as a step in the rehabilitation of the plant.

Not alone is it possible to increase freeboard, increase wash rate and secure better distribution of wash water as a result of having installed the porous plates, but such procedure permanently removes from the plant the problem of the gravel layer. Far more filter ills may be traced to deficiencies in a gravel layer than is often suspected. Porous plates as a substitute for the gravel have much merit.

Discussion by Harry T. Campion.* Porous plates are used for the underdrain system in Filter 4 at the Grand Rapids Filtration Plant. The installation was completed and the filter placed in service May 23, 1936. About one thousand million gallons of water have passed through it.

The porous plates are meant to serve simply as a support for the sand and as a means for distributing wash water, not as a filtering medium. Therefore, it would seem that in a plant using simple coagulation, when flocculation is efficient and the filtration is thorough, there would be nothing in the water to cause clogging of the plates. However, where lime or lime-soda softening is the process of treatment used, deposits of calcium carbonate incrustation may and most certainly will occur.

At the Grand Rapids plant where the water is lime softened, the sand filter has always been an important part of the softening process. In passing through the filters the drop in alkalinity may vary from 10 to 18 p.p.m., depending on efficiency of the softening reactions and the extent of recarbonation. The filter sand grows in effective size each year and when the size reaches about 1 mm. the sand is discarded and new sand hauled in from a neighboring pit. Cost is low, being mainly labor and hauling. With the installation of porous plates the extent of incrustation became of much greater importance. The effective size of the sand in Filter 4 increased from 0.31 mm. in 1936 to 0.49 mm. at the present time. We found, however, by sampling water at different depths in the filter that between 80 and 90 per cent of the total drop in alkalinity, while passing through the filter, occurred in the top 12 in. of sand. We also found that there was some drop in the alkalinity in passing through the plates. This incrustation by calcium carbonate does not, of course, need to continue. It could be stopped by the use of sodium hexametaphosphate, or we could radically reduce it by increased recarbonation. Both of these methods would, however, add to the cost of water and both would slightly increase the total hardness.

From the first, it was expected that at some time the plates would have to be cleaned. The practice of cleaning pipe lines, conduits, etc. with inhibited acids is becoming quite common and there is no reason why some such treatment could not be used on filter plates.

* Chief Chemist, Filtration Plant, Grand Rapids, Mich.

In fact just for experiment, we cleaned about a dozen of the plates with a weak acid and it seemed quite easy and the effect was noticeable. At present the plates foam when acid is applied. The work of throwing back the sand and sweeping the plates clean with a broom is a job requiring only a short time.

The primary purpose of this discussion is to relate the present condition of the plates. We have from time to time uncovered some of them for inspection. There is not the slightest indication of any loosening of bolts or iron supports and the cement joints seem as good as the day they were put in. Initial loss of head is no greater than it was in 1936. Filter runs are normal, in fact they average slightly greater on Filter 4 than on the balance of the filters in the plant. The fact that there is some clogging is indicated in washing the filter. In 1936 the measured vertical rise of wash water was 32 in. per min. while at present it averages about 27 in. per min., a drop of 5 in. per min. Due to the design of the unit, the method of measuring this rise is open to some question but it is believed that the above figures are fair. It happens, however, that 27 in. rise per min. of water is greater than the average from other filters. The writer is still of the opinion that porous plates are the correct solution for filter underdrain troubles at Grand Rapids and hopes that in the near future additional filters can be so equipped.

There does seem to be some variance in the success reported from installations of porous plates and the adaptability for different types of water. The writer recommends that wherever possible, an experimental filter, using one or more plates, be tried first. The plates must be so installed that they cannot be dislodged during backwash operations.



Committee on Water Works Practice

To the Board of Directors, American Water Works Association:

There is submitted the following report of the activities of the various sub-committees of the Committee on Water Works Practice—as of January 10, 1940.

1. *Chemical Hazards in Water Works Plants.* This committee has prepared three valuable reports; one on chlorine, one on ammonia, and the third on sulfur dioxide and caustic soda. The chairman of the committee is maintaining contact with certain representatives of the chlorine industry because of the expressed interest of this Association in fusible plugs for chlorine containers.

2. *Electrolysis and Electrical Interference.* The activities of this committee are made evident through its cooperation with the "American Research Committee on Grounding." Following an expression of interest in this subject by the Board at its last annual meeting, there was included in the statement of Association activities which went to all members under date of January 31, 1939, the following paragraphs:

"A special meeting of the Research Committee on Electrical Grounding was attended by several of the directors. A report was made to the board and, while no definite action was requested, the Secretary was instructed to advise all members with regard to certain phases of the problem.

"You are therefore advised that while the practice of grounding electric service lines on domestic water service pipe is in effect in many cities, the water department does not place the connections, derives no benefit from them, may be damaged by them, and tolerates them only because of their reputed importance in providing electric service. While the water supply industry as a whole does not accept responsibility for the providing of means of disposal of stray or waste electric current, water department executives are advised not to order the removal of electrical grounds of alternating current systems from water pipes unless they have been informed by

competent legal counsel that such removal order can be supported in the case of court action."

3. *Pipe Line Coefficients.* This committee has collected a considerable amount of data but no record is in hand which would indicate the probability of early completion of the committee's work.

4. *History of Water Purification.* Mr. M. N. Baker, who is handling this work, continues his collection of interesting material. He has given no recent statement which would indicate that he considers his research nearing completion.

5. *Basic Data.* This committee cooperated with certain federal departments in the preparation of a form of questionnaire to be submitted to all water departments in the United States. That coordinated activity did not eventuate. In the meantime, the United States Public Health Service has established in Cincinnati, in connection with its research laboratory, a department to which is assigned the duty of collecting information concerning the water supply treatment works and sewage treatment works in the United States. During the year, the Engineering News-Record as a public service collected and published a condensed survey of Water Supply Works and Sewage Treatment Works in the United States. The United States Census Department, as a part of the 1940 census, will obtain certain information concerning the availability of public water supply in residential property. Occupants will be asked whether there is (1) running water within the dwelling unit, (2) hand pump within the dwelling unit, (3) running water outside the dwelling unit (piped), (4) other outside water supply within fifty feet of dwelling unit, or (5) other outside water supply fifty feet or more from dwelling unit.

Census takers will ascertain what the toilet facilities are with regard to (1) flush toilet within structure for *exclusive use* of the household, (2) flush toilet within structure *shared* with other households, (3) chemical or other non-flush toilet within structure, (4) outside toilet or privy, or (5) no toilet or privy. With regard to bathroom facilities, representatives of the Census Bureau will ascertain whether the dwelling unit is equipped with (1) bath tub or shower with running water within structure for *exclusive use* of the household, (2) bath tub or shower within structure *shared* with other households, or (3) no bath tub or shower within structure. The Census of Housing will be the first undertaking of the federal government in this field on a nationwide scale.

6. *Ground Water Collection.* This committee, which is organized solely in the person of the chairman, has made no progress during the year. A new committee, later discussed, has been established to develop specifications for drilling wells and centrifugal well pumps.

7. *Quality and Treatment of Water.* *The Manual on Water Quality and Treatment* is in the hands of the printer, being put into page proof form. It should be available within the next sixty days as an Association document.

8. *Power and Pumping.* This committee, organized solely in the person of its chairman, has made no recorded progress during 1939.

9. *Steel Plate Pipe.* This committee has made remarkably fine progress during 1939. There appeared in the January, 1940 issue of the Journal, a series of tentative steel plate pipe specifications under the following headings:

7A.1—A. W. W. A. Tentative Standard Specifications for Riveted Steel Pipe

7A.2—A. W. W. A. Tentative Standard Specifications for Lock-Bar Pipe

7A.3—A. W. W. A. Tentative Standard Specifications for Electric Fusion Welded Steel Water Pipe for Sizes 30 Inches and Over

7A.5—A. W. W. A. Tentative Standard Specifications for Coal-Tar Enamel Protective Coatings for Steel Water Pipe for Sizes 30 Inches and Over

7A.6—A. W. W. A. Tentative Standard Specifications for Coal-Tar Enamel Protective Coatings for Steel Water Pipe for Sizes $4\frac{1}{2}$ Inches Outside Diameter up to but not Including 30 inches.

7A.7—A. W. W. A. Tentative Standard Specifications for Cement-Mortar Protective Coating for Steel Water Pipe for Sizes 30 Inches and Over

These tentative specifications are being published for the information of the water works field under the authority specifically granted by the board at its meeting June 5, 1939. The progress made by this committee deserves the fullest commendation. The committee, and the chairman of the committee, have had the cooperation of the manufacturers of steel pipe and pipe coating materials. A conference of certain committee members and manufacturers was held in Chicago during the week of September 12, 1939. At that time, the manufacturing group organized themselves into a "Steel Pipe

Manufacturers Advisory Committee." It has the full approval of the chairman of the Steel Plate Pipe Committee and is approved in principle by the chairman of the Water Works Practice Committee.

It should be noted that the organization as set up involves the addition to the Association's committee, which now consists of:

William W. Hurlbut, <i>Chairman</i>	Frank A. Barbour
William W. Brush	George H. Fenkell
Fred M. Randlett	John F. Skinner
Thomas H. Wiggin	

of the following men who represent the manufacturers:

Russell Barnard
George B. McComb
C. S. Patton.

It is broadly proposed that this Steel Pipe Manufacturers Advisory Committee will hold meetings during the general convention of the A. W. W. A., at which time discussions of the general subject will be carried on and reports of research or new developments made. The general recommendations of the Steel Plate Advisory Committee will be conveyed to Committee 7A by Messrs. Barnard, McComb and Patton. Specific approval of these arrangements by the board is requested. The tentative specifications, which appeared as part of the January, 1940 JOURNAL, are scheduled for discussion at the time of the Kansas City Convention and a further report upon the subject will be presented to this board at one of its meetings during that convention.

10. *Reinforced Concrete Pipe.* This Association has no committee upon this subject at the present time. The interest of the field is developing to such a degree that it appears advisable to establish such a committee and organize it definitely for immediate activity. (The board authorized such a committee.)

11. *Cast Iron Pipe.* Members of the Association received, as a part of their December, 1939 JOURNAL, an assembly of three specifications approved by the A. W. W. A. as one of the sponsors of A. S. A. Committee A21. A report of the committee on "Coal-Tar Dip Coatings" is now in the office of the editor of the Association's JOURNAL for final detailed work. It will be preprinted for the use of Committee A21 in obtaining approval of the committee members

of the sponsor societies. It will later be submitted to the Committee on Water Works Practice and the Board of Directors of this Association in its position of responsibility for such matters within the A. W. W. A. When approved, it will appear in the JOURNAL. The material published in the December, 1939 JOURNAL is being reprinted in the form of separate documents and will be sold by this Association to all persons interested in the use of the document.

12. *Laying Cast Iron Pipe.* This committee is at present carrying on no work. It is evident, however, that within the next two or three years it may be advisable to ask that the committee review certain details of its report related to the sterilization of water mains.

13. *Distribution System Records.* A very fine Recommended Practice document has been prepared under the leadership of Chairman W. V. Weir. It has been approved by the Committee on Water Works Practice. Copies of it have been sent to all members of this board. It is now recommended to this board for approval with the request that its publication in the JOURNAL of the Association be authorized, with reprints to be printed and sold at a price estimated to cover their cost. (This report was approved by the board and published in the February JOURNAL.)

14. *Valves, Sluice Gates and Hydrants.*

14.1 *Gate Valves.* Standard specifications for gate valves which were adopted by this Association in 1938 were published as a formal Association document in the JOURNAL for March, 1939. A large number of reprints of this set of specifications have been distributed in the water works field.

14.2 *Sluice Gates.* Under the chairmanship of Mr. Wm. R. Conard, a preliminary consideration has been given to the assembly of specifications for sluice gates. A communication from the chairman under date of January 10, 1940 submits for comment a first draft of proposed specifications for sluice gates.

14.3 *Specifications for Fire Hydrants* have stopped short of completion because of differences of opinion concerning the necessary thickness of the hydrant barrel. (The board discussed this subject fully and adopted as a schedule for barrel thickness, the dimensions of class 250 pipe of the same diameter.)

15. *Meters.* The committee charged with revision of the Association's present standard for water meters of the domestic disc type has made fine progress. No tentative report in the form of new specifications is, however, yet available. Active interest in this

committee's work, both on the part of the consumers as well as the manufacturers, justifies the establishment of this committee.

16. *Steel Standpipes and Elevated Tanks.* Mr. L. R. Howson, chairman of this committee, has within the last year also been made chairman of the American Welding Society's Committee on Welded Steel Tanks. He also represents this Association on the N. F. P. A. Committee on water tanks. Mr. Howson and his committee are actively at work and promise that a revised specification will be available for discussion by the time of the Kansas City Convention.

17. *Fire Prevention and Protection.* This committee should be considered in connection with the N. F. P. A. Committee on Public Water Supplies for Private Fire Protection. Mr. John H. Murdoch, Jr. is chairman of the Committee on Fire Prevention and Protection and Mr. J. Walter Ackerman is a member of that committee and represents the Association on the N. F. P. A. committee. The demands upon Mr. Murdoch's time in his professional activities are such that he has been unable to give the needed attention to this very important topic. While public water supply departments are called upon to assume definite duties with relation to fire protection, the water works field generally lacks a well integrated understanding of the special nature of the service and the extent of the capital investment involved. In times past, under the leadership of Mr. Nicholas H. Hill and Mr. Frank C. Jordan, the Association found means of expressing its position more adequately than has been the case within recent years. It appears important to relieve Mr. Murdoch of his duties as chairman of Committee 7L and to give Mr. Ackerman some respite from his duties on the N. F. P. A. committee. Mr. C. J. Alfke, general manager of the Hackensack Water Company appears to be willing to represent the Association on the N. F. P. A. committee. Having the approval of this board and the understanding on the part of the board that a change would be intended to develop the Association's viewpoint more aggressively, it is the intention to substitute Mr. Alfke for Mr. Murdoch as chairman of Committee 7L, and for Mr. Ackerman as representative on the N. F. P. A. committee.

18. *Distribution System Safety.* Professor Wm. E. Stanley, chairman of this committee, is carrying on a very fine program of activity, looking toward a "Recommended Code of Distribution System Safety." The presentation of the viewpoint of the committee may be anticipated at the time of the Kansas City Convention.

19. *Service Line Materials.* It is to be regretted that this committee has not yet brought this work to completion. A questionnaire memorandum was circulated by the chairman of the committee under date of April 5, 1939 and it appears proper for the chairman of the Water Works Practice Committee to request the chairman of this sub-committee to bring his work to completion and report by the time of the Kansas City Convention, unless some essential study now in progress requires an extension of time. (The chairman of the committee promises the report.)

20. *Transite Pipe.* No current activities of this committee are reported.

21. *Welding of Steel Standpipes, Elevated Tanks and Pipe.* The activities of this committee, insofar as they relate to welded steel pipe, are consolidated in the reports of Committee 7A. Insofar as they relate to steel standpipes and elevated tanks, they are consolidated with the activities of Committee 7H.

22. *Cross-Connections.* Mr. E. Sherman Chase, chairman of this committee, promises a further review and report upon this subject for the Kansas City Convention.

23. *Deep Wells and Deep Well Turbine Pumps.* A committee has been formed to develop specifications on these items. A discussion of the need for this activity appeared in the January, 1940 JOURNAL. Messrs. J. A. Carr and J. C. Harding have been appointed co-chairmen of this committee. Mr. Reeves Newsom, as vice-chairman of the Committee on Water Works Practice, is in contact with the work. The committee personnel is now being set up.

Water Purification Division Committees

24. *Specifications and Tests for Water Purification Chemicals.* Chairman Braidech promises completion of this work in time for reporting at the time of the Kansas City Convention.

25. *Activated Carbon Research.* This is an active committee. Special conference was held by it during the Atlantic City Convention. A recent meeting for purposes of evaluating odor test methods was held in Springfield, Illinois, in December, 1939. The committee will have another review session during the Kansas City Convention.

26. *Methods of Testing Zeolites.* The former committee prepared a report which has not been printed in the JOURNAL but which is available in mimeographed form upon application to the Association's

office. The Water Purification Division has, during the past year, organized a new committee on Specifications for and Methods of Testing Zeolites. Its scope includes both base exchange and carbonaceous zeolites. D. E. Davis, of Pittsburgh, is the chairman of the new committee.

27. *Methods of Determining Fluorides.* Chairman A. P. Black promises a final report of his committee at the Kansas City Convention.

28. *Chlorine-Ammonia Treatment.* This committee has not made conspicuous progress. A discussion of the work of the committee will be held under the leadership of its chairman during the Kansas City Convention. It appears proper to suggest to the Water Purification Division the advisability of requesting this present committee to report fully by the end of 1940.

29. *Coordinating Committee on Methods of Water Treatment and Laboratory Control.* This committee, under the chairmanship of Geo. D. Norcom, has rendered an important service to the Association by organizing two panel discussions on water quality which were made part of general convention sessions of the Association. The committee also has carried on two annual reviews of experiences of state sanitary engineers with obscure epidemics presumed to be associated with public water supplies. The absence of material volume of positive data returned by the state sanitary engineers would appear to indicate that the responsibility of public water supply for obscure intestinal outbreaks is neither so definite nor so widespread as had been assumed before the committee activities were undertaken.

30. *High Rate Treatment.* The Water Purification Division is faced with the necessity of reorganizing this committee due to the resignation of its previous chairman. No work is now in progress.

31. *Water Treatment Methods to Prevent Corrosion.* No record of the activities of this committee has been received.

32. *Standards of Purification Plant Operation.* The Water Purification Division has, during the present year, established a committee on this subject under the chairmanship of Mr. Edw. S. Hopkins of Baltimore. The committee is actively engaged in a review of the control methods and personnel relationship in water purification plants. A statement by the committee will be presented during the Kansas City Convention.

33. *Filler Sand and Gravel.* The Division has agreed to establish a committee to develop specifications for filter sand and gravel. It is almost unbelievable to realize that the A. W. W. A., in its long-term interest in water treatment and its many presentations of papers on filter characteristics, has not developed a set of minimum standard specifications for sand and gravel used in filters. This definitely will be corrected by the activity of the new committee.

Finance and Accounting Division Committees

34. *Administrative Problems of Joint Water and Sewage Departments.* This committee, organized during 1938 and headed by Frank O. Wallene of Cleveland, presented a report of committee investigations which has been published in the JOURNAL.

35. *Lien Laws.* This committee, consisting of Mr. Meites, of Chicago, as chairman, and Messrs. Lenhardt of Detroit and Schwartz of Newark, has been organized to make a national review of the laws and ordinances which may be invoked by water departments to enforce collection of water bills.

36. *Uniform Classification of Accounts.* The National Association of Railroad and Utilities Commissioners is actively developing regulatory material which affects water utilities. Mr. L. D. Blum acts as chairman of a special liaison committee to present the views of the A. W. W. A. and to bring the N. A. R. U. C. material to the attention of the A. W. W. A.

Joint Committees with Other Organizations

37. *Standard Methods for the Examination of Water and Sewage.* The committee which is charged with the publication of the well-known text of *Standard Methods* is now in the process of reorganization, looking toward the production of the ninth edition. Mr. Powell, who has been one of the representatives of the A. P. H. A., and Mr. Jordan, who has been one of the representatives of the A. W. W. A., each find it necessary to detach themselves from this activity. Conferences have been held with Dr. Atwater, Secretary of the A. P. H. A., Mr. Wolman and others and agreement is nearing completion which should result in the appointment of Dr. M. C. Schwartz, of the Louisiana Experiment Station as one of the representatives of the A. W. W. A., and Dr. W. L. Mallmann, of Michigan State College, as one of the representatives of the A. P. H. A. Dr.

Schwartz is highly expert in matters of boiler feedwater treatment, and Dr. Mallmann is expert in bacteriology laboratory routine. The reorganized committee will then consist of Messrs. Buswell, Mallmann and Norton representing the A. P. H. A., and Hatfield, Leverin and Schwartz representing the A. W. W. A. When the appointments have been approved, the present plan is to call the committee together for purposes of reorganization looking forward to production of the ninth edition of the text. The preliminary organization meeting can also be expected to continue as a preliminary scheduling meeting in which various parts of the revision will be assigned to members of the committee for their direct handling.

38. *Joint Research Committee on Boiler Feedwater Studies.* A report from this committee appears at the end of this report.

39. *American Research Committee on Grounding.* This is discussed under section 2.

40. *Water Works Terms.* This committee works under the general direction of Mr. Thorndike Saville. This activity has been headed up into the office of the Water Resources Committee of the National Resources Planning Board. The chairman of the committee anticipates his ability to distribute mimeographed copies of the second revision of the glossary of terms within the next sixty days.

41. *Water Works Accounting Manual.* This joint publication, produced under the leadership of Mr. Carl H. Chatters, of the Municipal Finance Officers' Association, and Mr. Hal F. Smith, of the A. W. W. A., is developing into a standard document of the water works accounting field comparable to the position of *Standard Methods of Water Examination* in the laboratory field. The sales continue at a reasonable rate.

A joint agreement was developed in 1938 looking toward the creation of an editorial board for revision of the *Accounting Manual*. While there is no evidence that immediate revision is indicated, it is being suggested to the Financing and Accounting Division officers that they proceed to nominate their representatives to the prospective editorial committee. This will establish the mechanism for revision whenever the necessity for such work arises.

42. *Joint Committee on Water Hammer.* This committee, which was organized in 1931, appears to have expended its energies in two symposia held during A. S. M. E. meetings. No activity is recorded since the 1937 meeting of the A. S. M. E.

A. W. W. A. Representation on Committees of Other Organizations

43. *Wrought Iron and Wrought Steel Pipe, Valves and Fittings.* Mr. S. T. Powell, representative of this Association on the committee, advises that no activities were current during 1939.

44. *Cast-Iron Pipe and Special Castings.* This A. S. A. activity has been previously discussed in this report under the heading of "Cast Iron Pipe Committee."

45. *Manhole Frames and Covers.* This A. S. A. committee under the sponsorship of the American Society of Civil Engineers and the Telephone group, has as A. W. W. A. representative, Frank A. Marston. Mr. Marston reports no work done during 1939, no communication received concerning the work of the committee, and closes his brief statement with the phrase "the work remaining to be done could and should be completed promptly." Mr. W. W. Brush, a member of this Association, represents the American Society of Civil Engineers in this enterprise. Messrs. Brush and Marston appear to agree that completion of the project has been impeded due to the reluctance of certain utility groups to accept the standardization of so important a structure as manhole frames and covers.

46. *Standardization of Plumbing Equipment.* During the year 1939, Walter S. Cleverdon was relieved of his duties as representative of the A. W. W. A. on this committee (A40) and Mr. M. Warren Cowles was appointed to succeed him. The sub-committee on air-gaps is approaching completion of its work.

47. *Pipe Thread.* Mr. W. W. Brush, who represents the Association on this committee, advises that the work is not progressing rapidly. No material has been submitted for final approval.

48. *Pipe Flanges and Fittings.* This committee, which goes under the colloquial term of B16, has completed its work on standardization of cast-iron flanges and cast-iron fittings; screw fittings; and steel flanges and flanged fittings. This committee's activities are highly useful in the mechanical and water works field. Its material produced is of a character which indicates the merit of such work.

49. *Code for Pressure Piping.* Mr. Frank N. Speller, who represents the Association on this committee, states: "The revised code will probably be printed in pamphlet form early in 1940."

50. *Dimensions, etc., of Wrought Iron and Wrought Steel Pipe and Tubing.* Mr. Frank N. Speller, who represents the Association on this committee, states: "Revised standards were approved by A. S. A. during 1939."

51. *National Electrical Code.* This work was discussed under item 2.

52. *Zinc Coating of Iron and Steel.* Mr. S. T. Powell, the Association's representative on this committee, advises that no work is presently in progress.

53. *Specifications for Sieves for Testing Purposes.* Professor Fair, who represents the Association, advises that a set of American Standard Specifications for sieves has been presented by the committee and adopted by the A. S. A. under reference Z23.1-1939.

54. *Standardization of Graphical Symbols for Use on Drawings.* Certain preliminary material has been circulated among the representatives of the various associations. Material which had relation to the water works field was referred to Mr. W. V. Weir, chairman of the Association's committee on Distribution System Records. Mr. Weir advises that he takes no issue with the material proposed by the committee and has used part of the suggested material in preparing his committee report.

55. *Pumps and Pumping Equipment.* This A. S. M. E. committee, which was presumed to have been organized in 1937, appears to have undertaken no work up to the present time. Mr. S. M. Dunn, of Los Angeles, representing the A. W. W. A., is anxious to be of service in this work.

56. *Sulfur Cements.* During 1939, in response to a request made by the A. S. T. M., Mr. Jos. P. Schwada, of Milwaukee, was appointed as A. W. W. A. representative to the inter-association committee being organized by the A. S. T. M. for the purpose of developing specifications for sulfur cement. Mr. Schwada has advised that the committee has as yet undertaken no activity.

57. *American Coordinating Committee on Corrosion.* This committee, also organized under A. S. T. M. guidance, has had one meeting and is at present engaged in compiling a digest of research on corrosion. Mr. W. F. Langelier represents the A. W. W. A. on this committee.

58. *N. F. P. A. Committees.* The Association is represented on four committees of the National Fire Protection Association. None of these committees were engaged in major activity during 1939.

Respectfully submitted,

MALCOLM PIRNIE,
Chairman,

Committee on Water Works Practice.

**Report of the Joint Research Committee on Boiler
Feedwater Studies to the A. W. W. A.**

The officers of the Joint Research Committee on Boiler Feedwater Studies again welcome the opportunity to present to the American Water Works Association a report of the activities of this Joint Research Committee covering the period January 1, 1939 through December 30, 1939.

During the year, considerable progress has been made in the major research project being sponsored directly by this Committee and through it by your organization and the other five sponsor societies, as well as individual companies not directly affiliated with those societies and organizations.

In connection with the Power Division of the A. S. M. E., a program of three important papers was presented at the New Orleans meeting of the A. S. M. E. and the Louisiana Engineers Society held in February, 1939. The attendance at both of these meetings and the reception given to the papers definitely indicated a continued and growing interest in the problems incidental to industrial waters including boiler waters.

Reports were presented to the American Boiler Manufacturers Association, the American Society of Mechanical Engineers, the American Railway Engineering Association and the American Society for Testing Materials. In the latter case, the report was submitted at and in conjunction with the session on water sponsored by the A. S. T. M. Committee D-19.

The work of subcommittee #1 on Coagulation and Sedimentation has not as yet fully passed from the formative state. No active research program is contemplated on the general subject of corrosion as it is felt that there is no specific problem, aside from two now being given active attention, that would command a widespread interest and justify general financial support. These problems are (1) intercrystalline cracking under the auspices of Subcommittee #6 and (2) reaction between Steel and Steam at High Temperatures, being carried out principally at Purdue University and supported in part by those affiliated with this Society.

The officers of the Joint Research Committee are arranging with your Secretary, Mr. H. E. Jordan, for certain papers to be presented at the annual meeting of your Association at Kansas City in April, 1940. These papers are to be in connection with the fundamental problem "Municipal Water Supplies in Relation to Industrial Use."

This subject is of particular interest in view of the increasing tendency for municipal water works to treat the water supply with lime or other chemicals which treatment may or may not have an effect on the water from the viewpoint of industrial use.

Subcommittee #6 has been extremely active in the problem of intercrystalline cracking and has submitted data of great value to many interested parties.

This Committee has been very active in determining the part played by various inorganic and organic chemicals in the phenomenon known as intercrystalline cracking of steel. The Committee has tested various types of apparatus and at the present time is endeavoring to obtain data in the field through the use of two different tests known as the "embrittlement alarm" and the "embrittlement detector" which can be attached to any stationary or locomotive boiler.

As a result of these data, the Subcommittee of the Boiler Code Committee on Care of Steam Boilers in Service is again active in connection with the problem of Code rules for inhibition of embrittlement.

The fourth progress report of Subcommittee #9 on patents was presented at the annual meeting of the Executive Committee held in December. This report shows that the committee has been active mainly in the compilation of abstracts of patents, both United States and foreign, which are related to the preparation of feedwater, or the control of boiler water. The patents cited by Chemical Abstracts through November, 1939 and by the U. S. Patent Office Gazette through October, 1939 have been included in this fourth progress report.

It was decided at the time that this report was presented to arrange with the A. S. M. E. to duplicate this report in detail in order that copies of same might be available for sale.

It is the intention to sponsor a very definite program at the Spring meeting of the A. S. M. E. in Worcester, Mass.

The Committee is extremely grateful for the support which has been accorded its research on embrittlement through the agencies of the several sponsor societies and associations and the individual members of these associations and we would like to recommend to you continued support of this extended research project.

Respectfully submitted,

J. B. ROMER,
Secretary.



Report of the Audit of Association Funds For Year Ending December 31, 1939

To the members of the American Water Works Association:

The By-Laws require that the Secretary shall have made an annual audit of the books of the Association.

The records for 1939 have been examined by the staff of Louis D. Blum & Co. The complete record of that examination follows.

Reference may be made to the audit for 1937 which appeared on pages 520 to 525 of the JOURNAL for March, 1938; and to the audit for 1938 which appeared on pages 570 to 574 of the JOURNAL for March, 1939.

There is also submitted a membership statement for 1938 and a comparative record for 1930-1939 inclusive.

Respectfully submitted,

HARRY E. JORDAN, *Secretary.*

February 24, 1940.

Mr. Harry E. Jordan, Secretary,
American Water Works Association,
22 East 40th Street,
New York City.

Dear Sir:

The audit of the books of account of your Association for the year ended December 31, 1939 has been completed and as a result thereof we submit the following described exhibits and schedule:

Exhibit A—Balance sheet, December 31, 1939

Schedule 1—Investments, December 31, 1939

Exhibit B—Statement of income and expenses for the year ended December 31, 1939

Exhibit C—Surplus account for the year ended December 31, 1939

Accruals for receivable and payable items as at December 31, 1939 are reflected in the balance sheet.

For the year 1939 the increase in the surplus, of \$7,399.56, as shown in Exhibit C, represents the excess of income over expenses per Exhibit B, of \$6,548.31, profit realized on redemption of \$2,000.00 principal amount of North American Edison Bonds, of \$195.00, and profit realized on the sale of \$6,000.00 par value New York City corporate stock, of \$656.25.

During the course of our examination we received the usual cooperation from your officers and their staff, and we take this opportunity of expressing our appreciation of the many courtesies extended to us.

Very truly yours,

LOUIS D. BLUM & Co.
Certified Public Accountants.

EXHIBIT A—BALANCE SHEET, DECEMBER 31, 1939

Assets

Cash in bank and on hand		\$19,077.31
Accounts receivable:		
Advertising	\$2,699.50	
American Public Health Association	773.08	
Royalties on Manual of Water Works Practice	22.50	
Reprints	494.49	
Sundry publications	170.20	4,159.77
Membership dues		270.15
Accrued interest on bonds		241.04
Inventories:		
Type metal	\$469.13	
Manual of Water Works Accounting	107.30	
Manual of Water Works Practice	15.00	
Index	124.74	
Specifications	131.40	
Reprints—Gorman & Wolman	200.07	
Census	1.50	
Membership certificates	29.04	
Brochure—Fuller Memorial Award	75.90	
Journal paper stock	2,406.42	
Production costs—Specifications of Committee A21	591.78	4,152.28
Office Equipment	\$6,931.49	
Less: Reserve for depreciation	3,223.92	3,707.57
Investments, per Schedule 1:		
Investments, at cost	\$46,221.11	
Excess of redemption value of United States Savings Bonds over issue price	380.00	46,601.11
Total assets		\$78,209.23

Liabilities and Surplus

Accounts payable	\$2,571.02
Membership dues—advance payments	12,439.33
Unearned subscriptions to Journal	1,158.52
Reserve for expenses of Carbon Research Committee	191.57
Surplus, per Exhibit C	61,848.79
Total liabilities and surplus	\$78,209.23

EXHIBIT A, SCHEDULE 1—INVESTMENTS, DECEMBER 31, 1939

SECURITY	PRINCIPAL AMOUNT	DATE OF MATURITY	PURCHASE PRICE
Alabama Power Co.	\$2,000.00	1967	\$1,932.50
City of Los Angeles, Water Works Bonds	2,000.00	1960	2,241.11
International Tel. & Tel.	3,000.00	1955	2,895.00
Province of Ontario	2,000.00	1946	1,690.00
Province of Ontario	1,000.00	1964	732.50
Province of Ontario	3,000.00	1942	3,105.00
Province of British Columbia	1,000.00	1951	1,000.00
Southern Pacific	5,000.00	1977	4,875.00
United States Savings Bonds (issue price)	(a) 5,250.00	1947	5,250.00
United States Savings Bonds (issue price)	(b) 7,500.00	1948	7,500.00
United States Savings Bonds (issue price)	(c) 7,500.00	1949	7,500.00
Certified check to the order of the Postmaster of the City of New York	(d) 7,500.00	1950	7,500.00
Total Securities	\$46,750.00		\$46,221.11
Excess of redemption value of United States Savings Bonds over issue price to December 31, 1939			380.00
Total Investments			\$46,601.11

(a) Maturity value at May 1, 1947—\$7,000.00. (b) Maturity value at December 1, 1948—\$10,000.00. (c) Maturity value at March 1, 1949—\$10,000.00. (d) On December 30, 1939, a check for \$7,500.00 to the order of the Postmaster of the City of New York was certified for the purchase of ten \$1,000.00 United States Savings Bonds at the issue price of \$750.00 each. These bonds were dated January 1, 1940 and received by the Association on January 5, 1940.

EXHIBIT B

STATEMENT OF INCOME AND EXPENSES FOR THE YEAR
ENDED DECEMBER 31, 1939*Operating income:*

Annual dues.....	\$37,845.56
Advertising.....	24,878.00
Subscriptions to journal.....	3,395.41
Convention registration fees.....	5,220.00
Convention extra tickets.....	2,087.50
Water Works Manufacturers Association.....	7,500.00
Interest on investments.....	1,137.24
John M. Goodell prize.....	75.00

Total operating income..... \$82,138.71

Publication income:

Sales of "Manual of Water Works Practice".....	\$240.00
Royalties on "Manual of Water Works Practice".....	44.50
Sales of "Manual of Water Works Accounting".....	703.51
Sales of reprints.....	2,395.27
Sales of specifications.....	387.44
Sales of census.....	14.51
Sales of index.....	15.25
Sales of membership certificates.....	142.30
Sales of proceedings.....	675.20
One-half of profits from sales of 8th edition of "Standard Methods of Water Analysis".....	773.08

Total publication income..... 5,391.06

Total income..... \$87,529.77

*Operating expenses:**Directors' and Executive Committee Meetings:*

Travel expenses—Annual meeting..	\$1,945.79	
Stenographic expense.....	113.65	
Executive committee expense.....	100.83	\$2,160.27

Administrative Expenses:

Rent.....	\$3,000.00	
Office supplies.....	3,172.94	
Membership promotion.....	364.55	
General travel expense.....	146.78	
Auditing expense.....	300.00	6,984.27

Administrative salaries:..... 25,440.18

Committee expense..... 819.19

Division and section expense:

Division expense.....	\$29.45	
Section—Membership allotment....	4,463.37	
Section—Official travel.....	1,900.51	
Section—General expense.....	222.15	6,615.48

Journal:

Printing	\$22,838.45	
Abstractors	667.62	
Storage—Journal paper stock	28.26	
1934-1939 index to journal	54.13	23,588.46

Convention:

General	\$1,303.58	
Entertainment	6,763.81	
Management committee	233.32	
Publicity and attendance committee	13.73	8,314.44

Membership dues in other associations 575.00

John M. Goodell prize 75.00

Brochure—Fuller Memorial Award 6.87

Association Publicity:

Salary of publicity and editorial assistant to Secretary	\$2,400.00	
Mailing expense	273.72	2,673.72

Depreciation of Office Equipment 451.25

Miscellaneous Expense 153.24

Total operating expenses \$77,857.37

Cost of publications sold:

Manual of Water Works Practice	\$178.85	
Manual of Water Works Accounting	360.74	
Reprints	2,181.87	
Specifications	185.52	
Census	7.25	
Index	7.56	
Membership certificates, including letter- ing and mailing	144.92	

Total cost of publications sold 3,066.71

*Development expenses:**Committee Expenses:*

Quality and treatment—Editing	\$26.63	
Hydrants and valves75	
Methods of determining fluorides	30.00	

Total development expenses 57.38

Total expenses 80,981.46

Net income for the year (Transferred to Exhibit C) \$6,548.31

EXHIBIT C

SURPLUS ACCOUNT FOR THE YEAR ENDED DECEMBER 31, 1939

Balance, January 1, 1939.....	\$54,449.23	
Add:		
Net income for the year, per Exhibit B.....	\$6,548.31	
Profit realized on redemption of North American Edison bonds, \$2,000.00 principal amount.....	195.00	
Profit realized on sale of New York City Corporate Stock, \$6,000.00 par value.....	656.25	7,399.56
Balance, December 31, 1939, per Exhibit A.....	\$61,848.79	

Membership statement for year of 1939

	ACTIVE	CORPORATE	ASSOCIATE	HONORARY	AFFILIATE	JUNIOR	TOTAL
January 1, 1939.....	2,839	276	186	20	34	4	3,359
Gains:							
New Members.....	484	30	19	5	28	12	578
Reinstatements.....	59	2	3				64
	3,382	308	208	25	62	16	4,001
Losses:							
Resignations and Deaths....	101	6	1	1	1	2	112
Dropped for non-payment of dues.....	162	8	7		2		179
Total December 31, 1939.....	3,119	294	200	24	59	14	3,710
Total January 1, 1939.....	2,839	276	186	20	34	4	3,359
Gain in Year 1939.....	280	18	14	4	25	10	351

Comparative Statement—Gains and Losses—Ten-year Period

YEAR	NEW	REIN- STATED	RESIGNA- TIONS AND DEATHS	SUSPENDED FOR NON- PAYMENT OF DUES	GAIN OR LOSS	TOTAL MEMBERS AT END OF YEAR
1930	501	39	121	134	+285	2,831
1931	203	22	123	216	-114	2,717
1932	117	22	169	297	-327	2,390
1933	168	56	159	234	-169	2,221
1934	271	66	86	122	+129	2,350
1935	565	42	85	190	+332	2,682
1936	311	53	104	218	+42	2,724
1937	514	86	122	139	+340	3,064
1938	520	59	144	140	+295	3,359
1939	578	64	112	179	+351	3,710
Total for 10-year period.....	3,748	509	1,225	1,869	+1164	



ABSTRACTS OF WATER WORKS LITERATURE

Key. 31: 481 (Mar. '39) indicates volume 31, page 481, issue dated March 1939. If the publication is paged by issues, 31: 3: 481 (Mar. '39) indicates volume 31, number 3, page 481. Material enclosed in starred brackets, ★[□]★, is comment or opinion of abstractor. Initials following an abstract indicate reproduction, by permission, from periodicals as follows: *B. H.*—*Bulletin of Hygiene (British)*; *C. A.*—*Chemical Abstracts*; *P. H. E. A.*—*Public Health Engineering Abstracts*; *W. P. R.*—*Water Pollution Research (British)*; *I. M.*—*Institute of Metals (British)*.

WATER SUPPLY—GENERAL

Report of the French Commission to the Congress of Liège, July 3-6, 1939. Regional Grouping for Public Supply of Potable Water. (For abstracts of Chapters I to VI, see *Journal A. W. W. A.*, 32: 173 (Jan. '40)). *Ch. VI. Grouping of Collectives. Administrative Organization.* Tech. Sanit. Munic. (Fr.) 34: 1411 (Sep.-Oct. '39). GASTON MONSARRAT: The intercommunal syndicate is best known and usually most practical grouping method; its administrative charter is clearly defined by Fr. law and commentaries and decisions thereon. Obstacles confronting creation of cooperative undertakings include individualism of component communities; opposition of the State to "a state within a state"; and reluctance of legislators to grant powers needed. For water supply projects, collectives should use grouping methods already authorized by law or demand legislation to create new methods. Besides intercommunal syndicates, alternatives now legally possible include: (1) Private individuals can give aid by grants of land, loans, labor, etc., to administrative organizations of water distribution systems, and can also form syndicate associations having right of expropriation, creation of certain taxes and borrowing by public subscription. Status of syndicate associations is clearly defined by Fr. law, and this method of grouping has been used in France for several yrs. Syndicate associations are also authorized to form unions among themselves for creation and development of water systems. (2) Two or more munic. councils can make agreements regarding communal enterprises at common expense, e.g. water supply; each council names representatives to a conference whose acts must be ratified by the member councils. (3) Syndicate commissions formed by cooperating municipal councils as in (2) can create waterworks system belonging indivisibly to several communities. If any such exist in France, practice in principle does not seem advisable for many difficulties are involved. (4) Syndicates of communities have power to form a new syndicate to extend water supply to isolated communities. Communities can

also form syndicates to insure control of water distribution concessions. Such syndicates have same power as individual communities to participate in private enterprises, e.g., water supply; they can thus facilitate water supply development by subscribing up to 40% of capital needed. (5) Although departmental (state) water distribution projects are authorized by law, none have been carried out. (6) Interdepartmental (interstate) agreements and conferences are authorized and are especially feasible for pipe line systems, though to date applied only to establishment of hospitals and other institutions. (7) So-called regional projects have not found popular favor because of Fr. wish to avoid re-creation of old provinces and "state within a state." However other regional groupings exist, e.g., military districts, and are feasible for water supply in certain cases, e.g., for an urban district wholly in one dept. or in several, or for scattered communities along an aqueduct. (8) It is too early to foresee a nat'l. water distribution program but studies such as present one lay basis for project. . . . Law specifies methods of calculating share of each property owner on property-valuation basis where costs of water purification system are to be assessed vs. private owners. However litigation often results. For intercommunity enterprises, costs are assessed in proportion to property valuation of each community in project by various methods, none free from criticism. To detn. interest of each community, quan. of water used or per capita valuation can also form basis. Whatever basis is chosen, corrections may be necessary on final results to compensate for increased distribution costs to small isolated places. General principles of assessing costs are same regardless of extent of cooperative unit concerned. Exact principles cannot be laid down to cover every case of grouping or financing but only broad principles enunciated. *General Conclusions.* F. DIENERT. *Ibid.* 34: 147 (Sep.-Oct. '39). Foregoing reports have shown that community grouping for water supply is to be recommended under proper conditions and can function smoothly. Rapid expansion in last 10 yrs. is due not only to economic causes but to overcoming of individualistic character in certain municipalities, e.g., in rural electrification schemes. Success of pioneer enterprises served as stimulus to other groups.—Selma Gottlieb.

Intercommunal Organization for Water Distribution in Belgium. (Belgian Reports to the Congress of Liège.) HACHEZ. *Tech. Sanit. Munic. (Fr.)* 34: 149 (Sep.-Oct. '39). *I. The National Society for Water Distribution.* Belgian legislation of '07 authorized formation of associations of communities for intercommunal water distribution only; in '22 this was expanded to include other public services. Since '07 law was not sufficiently used, act was passed in '13 forming the National Society for Water Distribution (NS) to educate the public, particularly in smaller places, to desirability of public water supplies, and to provide practical assistance. The NS does not hold a monopoly and no one is obliged to use its services. It is organized like a cooperative society but preserves the civil character and legal advantages of a commercial society. Formed by the State, the 9 Belgian provinces and communities served by it, the NS has its statutes, administrative council, supervisory committee, and general assembly. Its capital, except for a 1,000,000 fr. fund dedicated to studies and expenses of general interest, is divided into separate

funds for each project; success or failure of any one project under the NS therefore does not affect other NS projects. Each project is separately financed and managed. The NS thus is really a federation of independent intercommunal groups having a common law and directed by same organism, the administrative council. It operates as follows: The NS begins studies either on its own initiative or by request of interested communities. It submits engineering plans and reports on financial and economic phases. Projects are financed by funds borrowed by the NS to be repaid jointly by the municipal councils concerned, the State and one or more provinces. The NS supervises construction; system usually includes one or more water sources, necessary equipment, pumping stations, and distribution system with house services or outside hydrants. The NS supervises operation of system, collects all revenues and pays all expenses. At end of each yr., after setting aside 5% for legal reserve, it distributes excess of receipts over expenditures to communities composing project according to their share in financing project. Neither the State nor provinces share in these payments; their capital advances are not repaid to them. Thus the NS serves communities as engineer, banker, contractor and accountant. It serves 191 communities composing 67 separate water projects with 145,000 services supplying 800,000 pop. Total investment is 375,000,000 fr. Most larger communities and many smaller ones in central and south Belgium now have water supplies. Duration of NS is not limited; it can be terminated only by act of Belgian general assembly. The administrative council has 7 members, 4 apptd. by the king and 3 by the general assembly of the organization. Private individuals can participate in the NS but have not done so. Some communities necessary to a given project have failed to subscribe funds, and State has advanced funds for them until their admission into the service. Annual rebate to each community cannot exceed its yearly payment on construction bonds. Further profits are set aside for extensions and repairs. When max. of this fund is reached, rebate is made to customers in reduced water rates. Water rates are fixed by administrative council, usually by agreement with the communities. Each project has a consultative committee required to advise on changes in water rates, admission of new communities to project, merger with another project, financing of project, etc., before decision by administrative council of NS. This last provision is to avoid difficulties due to extreme jealousy of their autonomy by Belgian communities. Besides serving intercommunity groups, the NS has also established and exploited local services affecting only one community when circumstances so demanded. II. *Water Distribution Service of the Antwerp Group.* *Ibid.* 34: 151 (Sep.-Oct. '39). VAN DER TAELEN: The Antwerp Waterworks Co., Ltd., an English company, was granted concession by city of Antwerp in 1872; system began operation in 1881. Contract stipulated that at end of concession (1931), all property of the company, material, plant and distribution system, were to revert free of charge to City of Antwerp. Co. at same time agreed to lay pipes in all sts. of the city and furnish 150 L. per capita per day. At end of concession, and after passing through the war years and depreciated currency, Co. had an accumulated debt impossible to amortize. Meanwhile service had been voluntarily extended by Co. to communities along pipe line and to suburbs. Neither city nor Co. wished to renew concession

on former basis. Under 1922 act of Belgian assembly, an intercommunal joint-stock co., the Antwerpsche Waterwerken Maatschappij was formed in 1930. Its capital was fixed at 120,000,000 fr. in 1000 fr. shares. At end of concession in 1931, City of Antwerp turned over to new co., all property rec'd. from English Co., for 35,000,000 fr. in shares. The English Co. turned over to new organization distribution system in outlying places for 27,125,000 fr. in shares. Of remaining 57,875,000 fr., 10,000,000 were subscribed by 12 suburban communities, and remainder by City of Antwerp. Antwerp and the suburbs granted 54-yr. exclusive concession to the new Co., equal to the duration of the Co. Certain members of the old council and all experienced personnel of the old Co. were retained by the new. The administrative council has 9 members, 6 apptd. by City of Antwerp, 2 by the English Co. and 1 by the suburban communities; 5 commissioners are elected, 3 by the city, 1 by the English Co. and 1 by the suburbs. The new Co. has served pop. of 600,000 for 9 yrs. and has functioned smoothly. It has also undertaken 70,000,000 fr. of new work without gov't. subsidy. III. *The Intercommunal Water Company of the Liège Group and Extensions*. Ibid. 34: 159 (Nov.-Dec. '39). HALLEUX: The city of Liège is surrounded by numerous industrial communities on both banks of the River Meuse. The Water Co. was organized in 1913 as a co-operative society under the 1907 law. It secured the necessary lands 40 kilometers from the group, built reservoirs and piped the water to the reservoirs of the communities, between 1921 and 1925. It serves 48 communities with 260,000 pop. Original capital subscriptions were based on water supplied; 40 m³. per 24 hrs. corresponded to 10,000 fr. share, though same payment at present time entitles community to only $\frac{1}{3}$ this vol. of water. State contributed $\frac{1}{3}$ of cost of all work and province of Liège subscribed 122 of original 434 shares, later in part turned over to new communities entering project. Co. receives 0.25 fr. per m³. of water for payments on shares and 0.50 fr. for maintenance. Each community establishes its own distribution system and is self-governing, though construction and collections are entrusted to the Co. Agreements of the communities with the Co. expire in 1945 and may be renewed for 20 yrs. Water bills are collected 3 times yearly. Domestic rates are 17.25 fr. per trimester for annual consumption of 30 m³., with excess at 2.25 fr. per m³. Industrial rate is 2.25 fr. per m³. for less than 100 m³. and falls to 1.25 fr. for more than 500 m³. Meters belong to the community. Semianually the Co. sends financial statements to member communities. Co. accounts are naturally separate from those of the member communities, which however have voice in Co. affairs through a general assembly which elects an administrative council and 3 commissioners. State and province appoint a member each to administrative council. IV. *Provincial and Intercommunal Water Association of the Province of Antwerp*. Ibid. 34: 160 (Nov.-Dec. '39). E. HUYBRECHTS: Officially called in Dutch "Provinciale en Intercommunale Drinkwatermaatschappij der Provincie Antwerpen", abbreviated "Pidpa", this cooperative society was organized in 1913 under the 1907 law. It now serves 42,000 pop.; projects under way will increase no. to 105,000. At start Pidpa had besides Province of Antwerp, 35 community associations including 150 communities; it now has 40 associations. Capital is divided into 1000 fr. shares; the province holds 1000 and each community subscribes one share for

each 1000 inhabitants. Since total pop. of province is under 1,000,000, province is assured of holding majority of shares. Cost of studies toward projects comes from capital; which otherwise constitutes guaranty and rotating fund. Community and Pidpa sign contract governing establishment and exploitation of water service. Associated in Pidpa are City of Antwerp and 12 suburbs already organized into group for their own water supply. (See II, above.) Pidpa is directed by general assembly, administrative council and supervisory committee. In general assembly each associate has vote proportional to shares held, but no one associate can vote more than $\frac{1}{3}$ of total shares issued or more than $\frac{2}{3}$ of shares represented at any meeting. Administrative council delegates part of its powers to a committee of direction assisted by 3 technical consultants. Original plan for one large water storage project to supply entire province has been abandoned for various smaller storage projects. Pidpa is by law allowed to borrow funds but to date has not done so. State pays 33% of cost of projects, and from 1935-38 paid additional 15-25% as unemployment relief measure; remainder is financed by province and communities interested. For the first few yrs., receipts will not be sufficient over current expenses to permit communities to pay interest and principal on debt; provincial and community treasuries will loan funds to make up diff. Management must establish legal reserve, next pay 4% dividend to associates and then distribute remainder to communities in proportion to water consumed. Community can amortize debt by special property tax. Occasionally a project is developed of sufficient size to furnish additional communities not at once participating in the project; until they join, their share is borne by State and province. Community groups in Pidpa include (1) 8 supplied with water by Pidpa; they hold 80 shares; (2) 24 not yet granting concession to Pidpa but planning to do so; they hold 99 shares; (3) the 8 associates served by the Soc. Antwerpsche Waterwerken Mij; Pidpa will probably never supply them but they are associates in practical interest, holding 444 shares, 302 of which belong to City of Antwerp. The statutes do not differentiate among the 3 groups and thus theoretically the City of Antwerp group, while not directly served by Pidpa, could direct it. Actually the province plays the preponderant role. By tacit agreement, representatives of group (1) are named to the administrative council and representatives of groups (2) and (3) ordinarily take little active part in administration. However certain administrators of Pidpa are also on the administrative council of the Antwerpsche Waterwerken Mij., thus facilitating cooperation between the 2 societies. Statutes of Pidpa are very flexible. V. *The Organization of the Brussels Intercommunal Water Company*. *Ibid.* 34: 163 (Nov.-Dec. '39). POLLET: This Co. was organized in 1891 to supplement water service in existence from 1857-91; in 1938 it distributed 51,954,502 m³. of water to 85 cities and towns having 1,470,000 pop. Originally organized for 30 yr. period as cooperative society, with min. capital of 600,000 fr. subscribed by the 9 communities founding it. Reorganized under 1907 law, its existence was increased to 90 yr. period; provision was made for possible purchase by State of all or part of its properties. Audits and certain matters of policy were to be referred to the king. In 1911 capitalization was increased to 14,400,000 fr. In 1922, the gov't. granted subsidy of $\frac{1}{3}$ of bond issue of 72,500,000 fr., apptd. a member to administrative council and required

Co. to furnish water to communities of the Brussels group and of Flanders. In 1933 the Co. merged with the water Co. serving Brussels itself and 2 other communities. From 1891 the Co. has concluded contracts covering (1) Communities of the Brussels group. For water delivered at city gates, contract is for 90 yrs. and for guaranteed min. consumption varying with community. Excess over min. is charged for at progressively increasing rate. Contract stipulates terms for adjudicating basic quan. provided on basis of demonstrated consumption over period of yrs. For distribution within city, Co. is granted monopoly and agrees to furnish water for all needs except washing streets and sewers. The Co. makes studies, installs and maintains system, and makes collections and disbursements. Contracts run until 2010, renewable for 15 yr. periods. Rates are fixed by the communities. (2) Cities and communities of Flanders and with the Intercommunal Society of Flanders. Water is furnished to the Flanders aqueduct. Contracts are for 90 yrs. from 1924 and renewable for 30 yr. periods. Max. daily vol., non-cumulative, is 36,000 m³. per day but may later be doubled. *Increased quan. are charged for at progressively increasing scale.* (3) Communities situated along pipe lines, which it serves either directly or through the National Society for Water Distribution. VI. Discussion. *The Intercommunal of Flanders. Ibid. 34: 165 (Nov.-Dec. '39).* J. VAN MEENEN: Brussels Intercommunal (BI) was pioneer in field, having been organized in 1891, long before it had any legal existence. After proving that storage available in the Bocq valley was notoriously insufficient, it planned to use the Modave supply but met strong opposition from industries of the Hoyoux valley, fed by the Modave. With aid of city of Ostend, also in need of more water, interest of Leopold II was secured and in 1905 permission obt'd. to use Modave water. According to contracts with the Flemish towns BI undertook all studies and construction and sold water to interested communities at before-the-war rate of 10 centimes per m³. After war, certain communities opposed revision or renewal of contracts. Meanwhile BI had pursued projects started before war and incurred additional expense. Finally Intercommunal of Flanders (IF) was formed and took over all installations from Brussels to Ostend, reimbursing the BI. The IF guarantees to take a min. and not to exceed a max. of 36,000 m³. of water, which it receives at Brussels, at price fixed for all Brussels communities. The IF has grown rapidly and its administrators are now seeking supplementary water sources. In 1933 the old water service of the City of Brussels joined the BI after negotiations of 2 yrs., showing how even important units end by coalition to form a common organism. Belgium is decidedly the cradle of intercommunity water organizations, though all are based on very different principles. Experience has shown that organization must be elastic, e.g., some intercommunals desirous of remaining free of gov't. subsidies have found it necessary to accept them. The intercommunal organizations have thriven because they are based on the motto of Belgium, "L'Union fait la Force." (In union there is strength.)—Selma Gottlieb.

A Dual Water Supply for Coulee's "Model Town." HENRY W. YOUNG. *Am. City 54: 4: 50 (Apr. '39).* Coulee Dam, Wash. is a small town built by the federal gov't. for housing administrative officials working on Coulee Dam.

Water supply system is dual, consisting of spring water for domestic purposes and river water for other uses. 985' of tile laid in cemented gravel collects 18 g.p.m. from springs in Fiddle Creek Canyon, about 200' above Administration Bldg. Small covered reservoir at springs holds collected water until it passes for $\frac{1}{4}$ mi. through 3" pipe to housed storage reservoir holding 167,000 gal. This 3" pipe is in wooden box of 1 sq. ft. cross section filled with diatomaceous earth to protect it against freezing. Domestic supply is softened to 30 p.p.m. in summer and 20 p.p.m. in winter by automatic zeolite system. Supply is limited in quantity and is not much more than is needed. Precautions have been taken against failure in any part of system. The river water is forced to an open utility reservoir of 322,000 gal. by pumps located in pier of nearby highway bridge. Distribution system is composed of 33,400' of 3" to 8" c.i. pipe. From street, copper pipe is used. Town is on slope and plenty of pressure is available.—*Arthur P. Miller.*

Summary Study of Water Resources in the Region Southeast of Central Massif (France). O. WASSER. *Tech. Sanit. Munic. (Fr.)* **34**: 34 (Mar. '39); also *L'Eau (Fr.)* **32**: 27 (Mar. '39). There are nine distinct regions in France where rainfall exceeds 1,500 mm. yearly. Of these nine the Cevennes region has the worst floods. Author advocates building of storage reservoirs to control these floods. This would accomplish three things: (1) prevent extensive flood damage; (2) provide normal water supply during periods of drought; (3) provide water for needed irrigation. He estimates that enough water to supply 2,400,000 people would thus be provided. Calls attention to fallacy of searching for problematical sources when such a huge source is easily available. Several tables and maps show basis for estimate.—*Willem Rudolfs.*

Rebuilding a Water Supply. J. F. BEARDEN. *Am. City* **54**: 2: 56 (Feb. '39). Walhalla, approx. 2,500 pop., is county seat of Oconee County, S. C. First water works constructed in '22 was inadequate by '25. In '28, 22 mil. gal. storage basin was built and in '31 modern filter plant put into operation. Last year it was again necessary to rebuild and enlarge water works system and first unit consisted of new pumping station $2\frac{1}{2}$ mi. beyond present storage basin and main water supply or about 9 mi. from town. These pumps are driven by gas engine. Next improvement was enlargement of storage basin and then a coagulating basin was constructed. Main supply line was enlarged from 6" to 8"—*Arthur P. Miller.*

Caisson Well Construction for Village Water System. PATRICK MANAHAN. *W. W. Eng.* **92**: 257 (Mar. 1, '39). Distributing system of Briarcliff Manor, Westchester Co., N. Y., consists of 26 mi. 4" to 14" c.i. mains with 425 gate valves and 250 fire hydrants, served from 2 well fields 20 and 24 acres in extent. In all 11 caisson wells, 2 drilled and 1 bored well supply system. Caisson wells of poured concrete, 15' inside diam. with av. depth of 33'. Water aerated.—*Martin E. Flentje.*

Warragamba Emergency Water Supply Scheme. ANON. *The Eng'r. (Br.)* **167**: 294 (Mar. 3, '39). A dam now being constructed across the Warragamba

R., New South Wales, Australia, as an emergency scheme to bring water to supplement that from the Nepean catchment area for water supply of Sydney. Preliminary scheme includes construction of a temporary dam across the river above the site of a proposed future dam; a pumping station; a tunnel connecting the reservoir and the pumping station; pipe line from the pumping station to Prospect Reservoir; and a balancing reservoir on high ground between the Warragamba and the Nepean rivers. Designed to deliver approx. 40 m.g.d. (Imp.).—*H. E. Babbitt.*

Aqueduct Operating Program. L. V. BRANCH. Eng. News-Rec. 121: 677 (Nov. 24, '38). Proposed program for operation of main Colorado R. aqueduct is described. Delivery to terminal storage at Cajalco Reservoir will usually be at flows which are multiples of 200 sec.-ft. Colorado R. water is and probably always will remain exceptionally free from bacterial contamination and industrial wastes. Lime-soda softening will be employed and as sludge disposal will be a problem, lime recovery from sludge, reducing latter by at least two-thirds, is being considered, recent experiments having indicated that recovery would be profitable. Delivery losses, i.e., seepage, evaporation, wasteway discharges, etc., are estimated at 16% when diversion is 200 sec.-ft. and 10% with flows of 500 sec.-ft. or more.—*R. E. Thompson.*

Saint Malo's Water System. M. H. VANDERZEE. Tech. Sanit. (Fr.) 33: 205 (Oct. '38). St. Malo (pop. 13,000) has a unique water problem, in that it is built on a barren granite rock almost entirely surrounded by the sea. Author discusses the history of this problem from the 11th. century to the present time. Its present needs (1500 cu. meters daily) are supplied by the reservoir known as the "Le Mervielle" constructed in the nearby municipality of Gasnier-Duparc. The filtration plant is described.—*Willem Rudolfs.*

Geology and Water Supply in the East Midlands. H. H. SWINNERTON. Surveyor (Br.) 96: 123 (Aug. 4, '39); Wtr. and Wtr. Eng. (Br.) 41: 467 (Sep. '39). The problem of supplying water to large areas looms largest in the public eye, but the problem presenting the greatest difficulties is that of supplying scattered rural districts. To meet these needs in the East Midlands, schemes have been produced jointly by several large centers, viz.: Sheffield, Nottingham, Derby, and Leicester. Two reservoirs have been constructed—Howden and Derwent, and a third—Ladybower, is in construction. Underground water is available in the area in three classifications: atmospheric, connate, and juvenile, the former being the most important underground source. The sandstones of the region include several of the finest water-bearing rocks of Britain. It should be noted that the limestones of the region may hold as large volumes of water as the sandstones, but the supply is more subject to seasonal variations. In the broad clay belts the problem of water supply presents the greatest difficulties. In some deposits lentils of gravel and sand occur which hold enough water to supply considerable villages, as well as many isolated farms.—*H. E. Babbitt.*

Water Supply Problems and Developments. W. H. MAXWELL. (Sir Isaac Pitman & Sons, Ltd., London. pp. 357). J. Royal Inst. of Public Health & Hygiene 2: 2: 134 (Feb. '39). "The author says in his preface that he believes the book will be of interest to Waterworks Engineers; he might have said also to Medical Officers of Health. True, it deals with engineering problems, but they are dealt with in such a manner, and with such a simplicity, that the Medical Officer of Health would find it useful when discussing such problems with his Authority, and in liaison with the technical branch. The notes on bacteriological and chemical analyses are well handled, and the description of modern methods of purification up-to-date and informative. The diagrams are clear, well noted and useful, even to the non-technical man. It is a most useful and valuable addition, not only to the Engineer and Medical Officer of Health, but to the Teacher of Hygiene."—*P. H. E. A.*

The Distribution of Water in Lyons (France). R. GIRARD. Génie civil (Fr.) 113: 208 ('38). Distribution in Lyons is in two sections separated by the Rhone. The Saint-Clair water works, serving the right bank, obtain supply from wells and infiltration galleries beside the Rhone. The water is chlorinated by the Verdun method as it is pumped. Cast iron pipes used exclusively in distribution.—*W. P. R.*

Sanitary Aspects of the San Francisco Water Supply. G. E. ARNOLD. Civ. Eng. 9: 722, (Dec. '39). Water supply of San Francisco is a chlorinated surface water augmented by deep wells. Water comes from three divisions: Peninsula, Alameda, and Hetch Hetchy. From the pollutional aspect all sources are exceptionally good. Water is normally free from objectionable taste or odor, although on occasions troublesome algal and weed growths in the Peninsula reservoirs cause complaint. Watersheds are owned by the Spring Valley Water system and those of the Peninsula are patrolled and habitation on them is limited almost entirely to employees of the Water Department. Camping is not permitted. Calveras watershed is largely privately owned and is used for stock grazing. Impounding reservoirs are of sufficient size to act as a natural agency of self-purification. Entire water supply is chlorinated and ammoniated and complete laboratory control over the quality of the water is maintained. So far as is known there are no unregulated cross connections in the water supply system. Source of supply is abundant for years to come and it is unusually safe from the health standpoint. No case of typhoid fever has ever been carried by the water supply, even before chlorination.—*H. E. Babbitt.*

A Visit to Columbus, Ohio. NATHAN M. WOLPERT. W. W. Eng. 92: 1422 (Nov. 8, '39). Clarence B. Hoover in charge of system and Charles P. Hoover supervises purification plant of Columbus, Ohio's water dept. serving city of 300,000. Supply taken from Scioto River. Copper used for services up to 2", c.i. for larger sizes. Water provided free to hospitals and charitable institutions, schools pay; street dept. pays \$500 per yr., sewer dept. furnished free. Mains are of Class B bell and spigot c.i. with Class D under R. R. tracks;

no mains placed on bridges. Hydrants (of N. Y. type) installed and maintained by fire dept., hydrants located on 6" branches. Meters owned by consumer, tested on complaint or meter reader's request; cleaned and repaired in shop by force of 12 men. Dept. has a 30 car garage with 1 man to service cars at night.—*M. E. Flentje*.

21-Mile Concrete Pressure Pipe Line and Dam Feature Bethlehem's (Pa.) New Water Supply. ANON. Pub.Wks. 70: 11: 9 (Nov. '39). Project now in progress to bring water from Wild Creek, 23 mi. from city, through 3 tunnels and 21 mi. of 36", 30", and 24" pipe line; to be finished late in '40 at total cost of approx. 3½ million dollars. Will replace present hard water supply from Lehigh River (filtered) and Illecks Mills wells. Consumption 7 m.g.d., yields new supply to be 12-16 m.g.d., new water soft, clear and of good sanitary quality. Dam to be of rolled earth with core of selected materials, 150' high, 1160' long impounding reservoir of 300 acres with cap. of 4 billion gal., drainage area—22 sq. mi. All the main line 24", 30" and 36" pipe steel cylinder, reinforced concrete pressure pipe.—*Martin E. Flentje*.

Aerial Engineering and Public Works. HERBERT THAYER BRUCE. Pub. Wks. 70: 11: 20 (Nov. '39). Aerial photographic surveys have proven satisfactory for water works as well as for other public projects. Photographs taken in overlapping strips with plane flying at proper elevation to get scale desired (elevation = desired scale in ft. times the focal length of lens used), each object taken 5 times. Mosaic and contour maps then made. Cost varies greatly—Middletown, Conn., with area of 42 sq. mi. aerially surveyed in 60 days at cost of \$4000.—*Martin E. Flentje*.

The Water Supply of London. Annual Report of the Metropolitan Water Board, 1938-1939. Wtr. and Wtr. Eng. (Br.) 41: 565, (Dec. '39). Quantity of water supplied amounted to 114,329.8 m.g. (Imp.) as compared with 112,857.5 m.g. (Imp.) the previous year. 65% was obtained from the Thames, 18% from the Lee, and 17% from wells and springs. Population supplied was 7,073,700. Storage capacity available represents 62.61 days supply. Storage and subsidence reservoir capacity for unfiltered water was 19,610.3 m.g. (Imp.). There is a total of 169 acres of slow sand filters, and 63 primary filters with an area of 30,864 sq.ft. Filtered water storage of 341.6 m.g. (Imp.) is available. Pumping engines, numbering 287, have a total horsepower of 58,962, and consumed 203,330 tons of coal. 100.86 miles of new mains were laid during the year, giving a total of 8,230 miles of mains. Expenditure of £408.851 was made for air raid precautions, and the personnel has been trained in routine to be followed after an air raid. Flow of the Thames represented a yield of 9.23 in. of run-off from a rainfall of 28.16 in. Lee yielded 5.69 in. from a rainfall of 26.05 in.—*H. E. Babbitt*.

Water Supply. Ministry of Health Annual Report for Year Ending March 31, '39. Wtr. and Wtr. Eng. (Br.) 41: 547 (Nov. '39). Average rainfall over England and Wales in 1938 was 34.9 in., as compared with 35.2 for the standard period 1881 to 1915. Expected depletion of water resources resulting from the

abnormal shortage of rainfall in the spring caused some restrictions on the use of water. Loans sanctioned by the Ministry for water supply schemes approximated £4,218,000 compared with £4,822,000 for the preceding year. It is estimated that piped supplies are now available for approximately $\frac{1}{2}$ of the rural population. Memorandum No. 221 was sent to all statutory water authorities under date of Jan. 31, '39, stating precautions necessary to the maintenance of wholesome water. These covered: (1) Possible infection through workmen; (2) The need for continuous observation of sanitary conditions at the source of supply; (3) The control of watersheds; (4) The need for frequent analyses of water, care in treatment, and the need to place reliance on more than one method of treatment; (5) The need for observing sanitary safeguards during construction on wells, mains and other works. The report contains recommendations concerning the administration of certain Acts relating to water supply.—*H. E. Babbitt.*

Rehabilitation Program of the Hammond, Ind., Water Works. LEO BESOZZI. *Am. City.* 54: 6: 82 (Jun. '39). During the past 5 yrs., Hammond, Ind. has made many improvements in its water works system. Those completed or in the process of construction include; (1) A modern purification plant of 20 m.g.d. capacity; (2) A 1.5 mil.gal. capacity elevated steel storage reservoir; (3) Various large water mains to improve the hydraulics of the primary distribution system; (4) Numerous smaller mains to eliminate dead ends in the secondary system; (5) Meter repair and storage building, garages and material storage yard; (6) Meter vaults and piping connections to permit the water to reach two adjoining towns. In operating divisions, laboratory equipment has been supplied to permit quality tests on purchases, more efficient systems installed to provide for prompter collection of revenues and efficient operating schedules set up for the filtration and pumping plants.—*Arthur P. Miller.*

Development of Water Works at Durham, N. C. ANON. *Am. City.* 54: 10: 65 (Oct. '39). First water supply of Durham was secured from the Nancy Rhodes Branch about 7 mi. northwest of the city where a 15' dam was built to create a lake about 1 acre in size. First elevated storage reservoir holding $3\frac{1}{2}$ m.g. was constructed in 1886. In 1899, the Durham Water Co. built a filter plant and further extensions were made in '02 and '10. In '16, the city bought the system and built a new $4\frac{1}{2}$ m.g. filter plant; at the same time increasing the pumping equipment. In '24, work was started on a new dam to impound 4 billion gals. of water. This was completed in '26. At the same time, new mains and pumping machinery were installed. Completing this series of improvements, there has been recently placed in service, a new $1\frac{1}{2}$ mg. elevated storage tank in E. Durham.—*Arthur P. Miller.*

57th Annual Report Board of Water Commissioners, St. Paul, Minn., 1938. Well tabulated and summarized report of water dep't. (Leonard N. Thompson Gen'l. Sup't. and Eng.) serving 306,000 of city's estimated 308,000 pop. Book value of property is \$18,158,000, net bonded debt \$5,274,000, '38 capital expenditures—\$355,874. Total revenue from sale of water was \$866,246, a decrease from '37 total of \$912,953; total revenue all sources—\$970,082. Operat-

ing expenses—\$475,355, an increase over '37 of \$4452. Revenue per m.g. pumped (1) 10 yr. av. and (2) '38 respectively, (1) \$116.68 and (2) \$116.34; same for administration costs, (1) \$15.41, (2) \$16.59; production costs—(1) \$14.49, (2) \$14.37; distribution costs—(1) \$21.58, (2) \$24.27; interest cost—(1) \$34.60, (2) \$33.62; sinking fund and serial bond requirements—(1) \$19.36, (2) \$24.03. Total amt. delinquent water bills, Dec. 31, '38—\$8851. 8156 mil. gal. water delivered to system; av. daily consumption—22.8 mil. gal., max. day—47.5 mil. gal.; consumption in gal. per day (1) per inhabitant—74.5, (2) per live tap—352, (3) per meter—325. Distribution system has 620.7 mi. of main, 38,345' added during yr.; cost of all repair and maintenance per mi. of system equalled \$59.36, with maintenance equal to \$26.81 per mi. Hydrants in use—5219, added in '38—22, av. maintenance cost per hydrant for yr. was \$3.87. Total supply station pumpage for yr.—9415 mil. gal. pumped at cost of \$4.23 per mil. gal., total distribution station pumpage 8338 mil. gal. at cost of \$7.45 per mil. gal. Av. dose chemicals used in treatment of water—alum, 1.2 g.p.g., cost \$2.18 per mil. gal.; chlorine, 0.88 p.p.m., cost \$0.54 per mil. gal.; ammonium sulfate, 0.014 g.p.g., cost \$0.11 per mil. gal.; total chemical cost \$2.83. Av. turbidity plant influent—2.6, effluent—0; av. 37°C count—influent 715, basin eff. 425, filter eff. 126, and plant eff. 5. Colon index—influent 4.28, plant eff. nil. Av. of filter wash water was 1.99%. Total hdnss. plant eff.—av. 180, alk. 149; pH 7.5; color 12.6. Report contains large number of tables and graphs in which statistical matter is well assembled and readily available.—*Martin E. Flentje.*

Fifty Years of Waterworks Advance. M. N. BAKER. *Eng. News-Rec.* **123:** 617 (Nov. 9, '39). Data given in *Eng. News-Record's* inventory (**123:** 414) are compared with those given in *Eng. News' Manual of American Water Works* published in 1890's. There has been 6-fold increase in no. of waterworks and even more striking increase in no. of works equipped for filtration, about 1 in every 6 being now so equipped compared with 1 in about 33 in 1890. Large no. of sewerage systems constructed has added to pollution of surface supplies, but this has been partially offset by parallel increase in sewage treatment plants. No. of sewage treatment plants in U. S. increased from 20 to 4,662 during period 1890–1938. Improved quality of water supplies is reflected in remarkable decline in typhoid fever death rate. Ratio of publicly-owned to privately-owned water works has increased from 1:1.2 to 2.7:1. In 1800 there were only 16 water works, only 1 being publicly-owned.—*R. E. Thompson.*

Palestine Rural Water Supplies. LESLIE T. COLBURN. *Surveyor* (Br.) **96:** 253 (Sept. 8, '39). Water program has been based on three essentials: conservation of rainfall by afforestation; provision of rural water supplies; protection of water in regard to health. Various types of pine saplings have been transplanted from nursery grounds to otherwise untillable areas. Water requirements of citrus production has been responsible for extensive private wayer supply developments. Government's program between '35 and '37 has improved over 200 rural works at an aggregate cost to the Government of £P52,000. Department of Health maintains sanitary service conducting

routine surveys and bacteriological analyses of water supplies. The economy of the region remains essentially rural, hence water is and will be essential to the country's existence.—*H. E. Babbitt.*

Water Supply Questions. NORMAN J. PUGH. Surveyor (Br.) 96: 247 (Sept. 8, '39). Possibility of forming a water grid similar to that of the Central Electric Board has been discussed. It will be an advantage when the present isolation of municipal water can be broken down. Limiting factor is the natural catchment areas into which the country is divided. Underlying principles of water charges are summed up in various Acts of Parliament. Basis of charges for domestic purposes is the *annual value* of the premises supplied. Annual value differs throughout the country and superimposed on this variation are the varying water rates which the authorities have power to impose. Basis of charges for industrial supplies is generally by meter. Payment is extracted from consumers in proportion to their ability to pay. Reason for metering is to secure payment for water used for special purposes. Universal metering would evoke in the poorer classes a tendency towards the sparse use of water.—*H. E. Babbitt.*

Water Supplies, Their Place in Our National Life. ANON. Surveyor (Br.) 96: 235 (Sept. 1, '39). Evacuation of cities raises question of adequacy and purity of water supplies in districts to which people are being transferred. It is in this connection that water supplies are being lifted from the neglect into which public opinion had permitted them to fall. Much has been done in the last 10 yrs. towards the construction of a system of water supplies coterminous with the nation itself, but many thousand parishes are still unable to provide efficient water schemes for sparsely settled areas. Scientific organization of our water supplies is as necessary for defense as the provision of aeroplanes and a navy. Question remains whether isolation and local autonomy should have more recognition than the interests of the nation at large. Water supplies of Gr. Br. fill too large a place in the welfare of the people to be the sport of political feeling.—*H. E. Babbitt.*

CHEMISTRY

Photoelectric Colorimetry. GEORGE P. ROWLAND, JR. Ind. Eng. Chem., Anal. Ed. 11: 442 (Aug. '39). In detn. of manganese with periodate, resulting MnO_3 solns. follow Beer's law up to 8.4 p.p.m. of Mn. Highly selective green light filter must be used for measurements. Substitution photometry is most convenient photoelectric method. If soln. contns. other colored ions, oxidized soln. can be bleached with few drops of approx. 0.01% H_2O_2 to obtn. I_0 value, or in special cases with sodium azide. Diphenyl carbazide-dichromate system was also studied.—*Selma Gottlieb.*

Quantitative Analysis Based on Spectral Energy. MORRIS SLAVIN. Ind. Eng. Chem.—Anal. Ed. 10: 407 (Aug. '38). Because certain limitations are inherent in detg. concn. of constituent from measurement of intensity of emission spectrum in spectroscopy, energy of spectral emission is proposed as basis of quan. detns. Experiments show that energy of spectral emission

in C are directly proportional to wt. of element present, and tabulation is given of results with Ca concns. (as CaO) from 0.21 to 34% in mineral samples. Presence of other elements appears to have no effect on the analysis. Av. error was 8.3% and max. error was 18.5%. C arc spectra are photographed in constant light source and energy of spectral emission detd. by examn. of photographic plate with densitometer.—*Selma Gottlieb*.

Chemical Analysis by X-Ray Diffraction. J. D. HANAWALT, H. W. RINN AND L. K. FREVELL. *Ind. Eng. Chem.—Anal. Ed.* **10**: 457 (Sept. '38). "This paper supplies tabulated data on the diffraction patterns of 1000 chemical substances and gives a scheme of classification which makes possible a routine and valuable use in the chemical laboratory of the Hull method of X-ray analysis." Included are various compounds of interest in study of corrosion or boiler scale. Method may be used for identification of an unknown, even when mixture was as many as four or five components. Diffraction pattern obtd. as series of lines in certain definite positions and of certain relative intensities is classified by grouping the three most intense lines into 77 divisions in range from 20\AA to 0.5\AA . Occasionally record of fourth and fifth lines is necessary. Diffraction patterns of unknowns are compared with indexed data for known substances. Sample ground to 200 mesh is loaded into Pyrex capillary tubes, sealed and exposed before camera in an x-ray powder diffraction unit for 6 hrs. at 30,000 volts and 20 milliamps. Measurements are made from developed film with measuring scale. Method is limited to solid crystalline substances. Although x-ray diffraction patterns give positive results, some substances give no patterns or give weak ones easily obscured by other substances. X-ray combined with spectroscopy is valuable, since former shows existing chemical and physical state of sample and latter shows all elements regardless of state in which they are present. Spectrograph is sensitive in region of small percentages where x-ray is not. X-ray gives certain information which microscope does not, and vice versa. Advantages as a technic supplementary to other analytical procedures are: (1) The substances present show in their true state of chemical combination. (2) The analysis is conclusive even though only minute amounts of material are available. This is especially valuable in examination of corrosion products from small pits or surface attacks. Identification of small deposits and sediments can also be readily accomplished. (3) Substances are analyzed directly in "as received" state and are not destroyed. (4) Different crystalline phases, states of oxidation or hydration and physical state are observable, e.g., various oxides of iron. (5) Process of preparing specimen and obtg. x-ray pattern is simple and economical. (6) Diffraction pattern film provides permanent record of the original data. Method is qualitative, or semiquantitative to within about 5% in favorable cases. Appended are 39 pages of powder diffraction data.—*Selma Gottlieb*.

The Chemistry of Sea Water. Elements Which Are Present in Traces. H. WATTENBERG. *Z. anorg. allg. Chem.* **236**: 339 ('38); *Kolloid Z.* **83**: 235 ('38). About 0.004 γ of gold per liter is present in sea water and the content of hydrogen ions is even less but they have a definite biological effect. At the surface

and at great depths a pH value of 8.1 is general; at a depth of about 400 m. the pH may fall to 7.6 owing to the carbon dioxide produced by dying plankton. Sea water is generally supersaturated with calcium carbonate. About 2 γ of iron per liter exists in true solution but 10 to 100 times this quantity exists in colloidal form or combined with organic matter. The content of dissolved iron diminishes at the time of the growth of plankton. The vertical distribution of gold is similar to that of plankton. 2.0-2.2 γ of uranium and $10^{-7}\gamma$ of radium are found; radium carbonate is possibly withdrawn from the water with calcium carbonate by organisms. About 50 γ of iodine are present per liter but up to 100,000 times this concentration is found in certain species of *Laminaria*. Silica varies from 10 to 1,260 γ per liter according to the distribution of siliceous algae.—W. P. R.

Determination and Occurrence of Aluminum in Sea Water. HELMUT M. HAENDLER AND THOMAS G. THOMPSON. *J. Marine Research, Sears Found. Mar. Res.* **2**: 12 ('39). Method used for detg. Al in sea water consists in pptg. Al at pH 6-7 with oxine, dissolving ppt. in mixt. of equal parts of 2N HCl and EtOH and coupling oxine with diazotized sulfanilic acid. As little as 0.002 mg. Al suffices for development of color with NaOH soln. after above treatment. Color follows Beer's law, is stable for at least 4 hrs. and is easily compared with blank.—C. A.

Standardization of Sodium Thiosulfate by Copper, Using Perchloric Acid. JOSEPH J. KOLB. *Ind. Eng. Chem.-Anal. Ed.* **11**: 197 (Apr. '39). Sodium thiosulfate solns. can be readily standardized against Cu dissolved in HClO₄, avoiding certain disadvantages of Cu-HNO₃ method. For 0.025 N Na₂S₂O₃, place 0.60 to 0.65 gram of 99.96% pure Cu in 100 cc. volumetric flask, add 6 to 8 cc. of concd. HClO₄ (about 11 M) and heat to boiling *in hood*. Boil gently until all Cu is dissolved, continue boiling for a few min., then cool slightly. Add equal vol. of water, boil 2 min., cool and dilute to volume. To 10 cc. portions, add 5 cc. of 1 N KI, let stand for 2 min. and titrate with Na₂S₂O₃ to pale yellow. Add 5 cc. of starch soln., titrate to near endpoint, add 1.5 to 2 grams of KSCN and titrate to disappearance of blue color. Check endpoint by addn. of 0.025 N I since at endpoint titration mix. is not white but flesh colored. Results check iodate standardization.—Selma Gottlieb.

The Standardization of Thiosulfate Solutions by Means of Copper and Copper Sulfate. H. W. FOOTE. *J. Am. Chem. Soc.* **60**: 1349 (Jun. '38). Because their purity is easily detd. Cu and CuSO₄ have advantages in standardization. Eq. wt. is high, especially for CuSO₄·5H₂O. Cu or Cu compds. are suitable for standardizing Na₂S₂O₃ solns. if a soluble thiocyanate is added to soln. just before endpoint to liberate I₂ adsorbed by CuI and thus make it available to thiosulfate. Using CuSO₄ mono- or pentahydrate, suitable wt. of salt was dissolved in 25 cc. of water contg. 2 cc. of concd. HCl, and 3 grams of KI were added. Liberated I₂ was titrated nearly to starch endpoint, and approx. 2 grams of NH₄SCN added to liberate adsorbed I₂. Endpoint is sharp, ppt. turning white. Average of 25 detns. with Cu and CuSO₄ shows no marked positive or negative trend from I₂ values, mean deviation from I₂ standard being 1 part in 1300 and max. deviation 1 part in 650.—Selma Gottlieb.

Alteration of Adsorption Properties of Charcoal: Activation of Charcoal in Different Gases at Different Temperatures. F. E. BARTELL AND LEWIS E. LLOYD. *J. Am. Chem. Soc.* **60**: 2120 (Sep. '38). Ash-free sugar charcoal ground to 300-350 mesh was activated as follows in various oxidizing atmospheres: "High Temperature Charcoal" (HTC) at 1000°C., "Medium Temperature Charcoal" (MTC) at 400°, "Low Temperature Charcoal" (LTC) at 250°. As measured by preferential adsorption from benzene-ethanol solns., HTC was extremely organophilic while LTC approached in adsorptive properties the hydrophilic adsorbent silica, MTC falling between. When suspended in water, HTC gave both positively and negatively charged particles, former settling rapidly and leaving only negative ones. This carbon gave acid adsorption from 0.01 *N* HCl but no base adsorption from 0.01 *N* NaOH. MTC and LTC gave only negative particles. MTC adsorbed base, while LTC adsorbed both acid and base.—*Selma Gottlieb.*

Determination of the Organic and Inorganic Phosphorus in Natural Waters. S. V. BRUEVICH AND A. A. KOSTROMINA. *J. Applied Chem. (U. S. S. R.)* **11**: 682 ('38). Detailed directions are given for detn. of phosphate by the method of Kalle (*C.A.* **31**: 5718°). The error in detn. of total P is about 3.4%. For detn. of sol. mineral and org. P filter the water (without previous acidification) then acidify with 2 cc. of H₂SO₄ per 100 cc. of water and allow to stand before carrying out the Kalle detn. For detn. of sol. mineral P, filter but carry the analysis in the same day without digestion. For detn. of total insol. P (suspended) add 2 cc. of H₂SO₄ per 100 cc. of water and allow to stand overnight. For detn. of total mineral P treat the sample with a-dinitrophenol, neutralize with NH₄OH to a yellow coloration, add 1 cc. of 10% H₂SO₄, dil. to the mark (100 cc.) and compare colorimetrically. Thirteen references.—*C. A.*

Color Scale for the Determination of Phosphates in Water. R. DANET. *Bull. Biol. Pharm.* **P. 512** ('37); *Chem. Zbl.* **2**: 740 ('38). For the determination of phosphates 10 cc. of the water are treated with 3 drops of molybdate reagent (1 gram ammonium molybdate, 9 cc. distilled water and 30 cc. 50% sulfuric acid) and two drops of tin reagent (0.1 gram stannous chloride, 5 drops dilute hydrochloric acid, and 5 cc. distilled water). The blue color obtained after 5 min. is compared with a color standard prepared from 5 cc. of 1 in 500 indigo carmine solution, 0.8 cc. of 1 in 500 nigrosin solution, and 0.1 cc. of 1 in 100 pierie acid solution made up to 100 cc. with distilled water.—*W. P. R.* (*See note following next abstract.*)

Improvement in the Chemical Analysis of Water. III. Determination of Phosphorus. WALDEMAR OHLE. *Angew. Chem.* **51**: 906 ('38). Molybdenum method was found best, not only for water analysis but also for soil, etc. Most intensive and persistent blue color was obtained with 0.25% cc. (NH₄)₂MoO₄-H₂SO₄ mixt. and 0.03 cc. SnCl₂-HCl mixt. for 25 cc. water or test soln. This corresponds to 12.6 mg. Sn⁺⁺ per liter of water. Samples of soil, etc., are subjected to oxidation by perhydrol (H₂O₂) and H₂SO₄, excess acid neutralized with NH₄OH to pH = 7.0 (*p*-nitrophenol) and exactly 2.0 cc. *N* H₂SO₄ added to eliminate color-deepening action of (NH₄)₂SO₄. Influence of Fe is elimi-

nated by use of KCN soln. Arsenates can be reduced to arsenites according to Kalle with thiourea. Many data and 27 references are given.—C. A. (See following note.)

Note:—An article entitled "The Determination of Phosphates in Natural Waters," by Dean M. Taylor, Assistant Sanitary Engineer of the Minnesota State Department of Health, appeared in the *Journal of the A. W. W. A.* **29**: 1983 (Dec. '37). At the request of the editor Mr. Taylor has made the following comments on the two preceding abstracts:

The Deniges or ceruleomolybdate method is the best known method for determining small quantities of phosphorus. It is simple and accurate and should be of value in the field of water analysis. The relative proportions of reagents and sample are important and these two procedures use proportions similar to those in most accepted procedures. The procedures would be simplified by using greater volumes of reagents because it is not practicable to measure out such volumes as 0.03 ml. of reagent as is done in Ohle's method. Ohle has applied his procedure to samples of soil, etc. and certain workers might find his method of particular value for specific determinations. It is interesting to note that Danet has developed color standards because the blue color starts to fade after about ten minutes and permanent standards would be of great value. However, no mention is made of the stability of these color standards.—Dean M. Taylor.

STREAM POLLUTION AND CONTROL

Pollution—and the Pocketbook. SETH G. HESS. *Munic. San.* **10**: 356 (Jul. '39). Public has often been reminded of menace and hazards of bathing in polluted water. However, it has not been reminded, nor does it realize, ever-present economic influence of polluted waters on the pocketbook. Investigations begun by Interstate Sanitation Commission disclose that moneys spent on maintaining extremely valuable resources would be fully repaid to a community by preserving property values, tax income and continued employment. In general, investigation covered losses to fish and shellfish industry and those resulting from abandonment of commercial and recreational areas. Of necessity, studies have been limited to specific areas but findings indicate the tremendous losses in the entire district. The present \$2,231,000 shellfish industry on Long Island represents less than 30% of former bedding area. The \$4,000,000 shellfish industry existing near Canarsie twenty yrs. ago is now lost through ban due to pollution. Total loss reported in this limited area alone, during 25 yrs. would have been more than sufficient to build sewage treatment works for protecting area. Loss in rentals of shellfish areas in Raritan Bay approximate \$27,000 annually since '17. Value of fish caught in L. I. Sound, Jamaica and Manhasset Bays in '35 was approx. \$143,000 less than in '30. In '10, the U. S. Geol. Surv. evaluated real estate depreciation due to pollution on the Passaic R. Complete deterioration of once famous Bergen Beach shore resort, Jamaica Bay, is described. Private enterprisers developed lands and established concessions and amusements at cost of \$5,000,000. Concessions yielded about \$700,000 annually. Hotel shore dinners used to approximate \$400,000 yearly. Kill von Kull River once attracted number of

bathing concessions. Now same waters are brackish gray, with surface aggregate of indigested wastes from sewers and industries. Pollution has driven everyone to distant amusement centers. Clason Point bathing beach, closed by the Dept. of Health in '13 because of pollution, represents an annual loss of \$1,000,000 to owners and concessionaires. Author estimates loss in capital investments at Canarsie and Bergen beaches at about \$6,762,085. Miscellaneous annual losses in areas studied approximate \$6,013,851. Total losses over 20 yrs. amount to \$127,039,105, a sum sufficient to build sewage treatment works to abate all pollution causing it. Shore front of 4 amusement parks surveyed represent 2½ miles. 187 miles of tidal shoreline in N. Y. City alone. This is an infinitesimal part of total losses sustained within Interstate Sanitation District.—*Ralph E. Noble.*

When Private Corporation Pollutes Water. LEO T. PARKER. *Munic. San.* 10: 243 (Apr. '39). It is elementary law that a property owner cannot recover damages for water pollution unless alleged wrongful act is proved to have been proximate cause of injury complained of. Case of *Midco Oil Corp. et al. v. Hull*, 75 Pac.(2d)1126. Various higher courts have held no person may avoid liability for acts resulting in water pollution unless actually cause was act of God. Case of *Magnolia Petroleum Co. v. Ford*, 79 Pac.(2d)588. Occasionally, a higher court renders opinion explaining detailed legal procedure for determining amount of damages recoverable by property owner for pollution of water. Case of *Sinclair Prairie Oil Co. et al. v. Seebeck et al.* 78 Pac.(2d)282. In weighing evidence jury should determine extent and period of flow upon plaintiff's premises; extent of damage, if any, naturally and proximately; reasonable right of riparian owner to use the water for domestic and other purposes, uncontaminated. Case of *Cimarron Valley Pipe Line Co. v. Holmes*, 78 Pac.(2d)403. A municipality is liable to same extent and degree as an oil company for polluting water. It may be liable in damages for construction of sewerage system which pollutes running water, or otherwise effects damage to property. If nuisance is permanent, measure of damages recoverable from city is depreciation in market value of the private property. If nuisance is temporary and may be corrected at reasonable cost, measure of damages allowable to property owner is diminution in value of use or rental of the property during continuance of nuisance. Cases: Sewage nuisance—*City of Madisonville v. Nisbit*, 39 S.W.(2d)690; *International v. Gibbs*, 36 S.W.(2d)961. Temporary damage—*Oklahoma City v. Page*, 6 Pac.(2d)1033. Poisonous substances—*Bradley v. Consolidated*, 298 Pac.324. Varied nuisances embodied in taking of private property without just compensation which violates the U. S. constitution—*Perry*, 139 Mass. 198. Delay in filing suit forfeits right of plaintiff to damages—*Thomann v. City of Rochester*, 176 N.E. 129.—*Ralph E. Noble.*

Technical and Social Aspects of Watershed and Reservoir Sanitation. C. A. HOLMQUIST. *Civ. Eng.* 9: 665 (Nov. '39). Pressure of public demand is leading to reconsideration of recreational use of watersheds and reservoirs. Factors controlling sanitation of watersheds and impounding reservoirs are as follows: (1) geographical, including climate, topography, geology, (2) use to

which watershed is put, (3) ownership of watershed, (4) type of control permitted by state and local laws, (5) extent and adequacy of supervision maintained over sanitary conditions on the watershed, (6) storage period provided by reservoir, or lake, in so far as this affects natural self-purification, and (7) effectiveness of final treatment. In majority of states it appears that basic law contains no specific reference to watershed sanitation, but in about 15 states state-wide regulations pertain to protection of public supplies. Laws of several states authorize state departments of health to enact regulations for protection of individual public water supplies. Admittedly protection of public water supplies from pollution is of paramount importance but impossible to formulate any simple quantitative measure of permissible pollution. Generally agreed that surface supplies exposed to accidents and willful pollution should be subject to minimum treatment by at least chlorination. Layman is inclined to give more weight to benefits of dilution in large lakes than to benefits of treatment. Recent construction of water supply reservoir at Springfield, Ill., to be used by public for recreational facilities indicates extreme case. Springfield supply is subject to complete treatment. Summary of main points in watershed and reservoir sanitation includes: (1) delivery of untreated water from use watersheds is menace to health, (2) all surface supplies should be treated, (3) restricted recreational use of watersheds of reservoirs is permissible provided degree of control, self-purification of reservoir, and final treatment are coordinated, (4) such restricted use does not appreciably increase pollution of the raw water, (5) sanitary protection of watersheds is first duty of water officials regardless of subsequent degree of treatment of water, (6) cooperation with public results in better protection than rigid control of uncompromising nature, (7) special regulations are needed where watersheds are not owned by municipalities or water companies, (8) special staffs are needed for adequate control of watersheds, and (9) special control of typhoid carriers is essential.—*H. E. Babbitt.*

Water Pollution Prevention. K. M. GRIFFIN. *J. Sci. Tech.* (New Zealand) 20: 44B ('38). Report on visit during which author studied problems and methods of sewage disposal and prevention of pollution of rivers in Great Britain, Canada and the United States. History of English legislation concerning river pollution is reviewed and drawbacks in existing law are pointed out. Establishment of voluntary Joint Committees such as West Riding of Yorkshire Rivers Board (administrative work of which is described) has done much to improve state of streams within jurisdiction of these committees. Mention is made of work of Water Pollution Research Board on disposal of beet-sugar and dairy waste waters and of surveys of river Mersey and river Tees. Number of sewage works in England give at least partial treatment to storm water which, if discharged untreated, would contribute considerably to river pollution. Pollution in the U. S. is less than in England only because receiving rivers and lakes are larger and therefore better able to handle pollution load. Difficulties in minimizing or preventing pollution arise from commercial interests and conflict interests of the large number of authorities concerned. Cities and states in the U. S. have ample powers under existing legislation to prevent water pollution; problem is to teach public to demand

higher standard. Advantages of formation of compacts whereby number of states co-operate in establishing minimum standards of pollution for all streams, harbors, etc., within their boundaries is compared with those obtainable by federal control. In Canada Lake Ontario is seriously polluted and general conditions seem worse than in the U. S. since sewage works are subsidized to lesser extent. Different standards adapted for sewage effluents are discussed and recent developments in methods of sewage treatment used in various works in the countries visited are described. Number of water works obtaining supplies from polluted sources were also visited. Author concludes that although in New Zealand pollution of streams and tidal waters by sewage and industrial wastes has not yet reached serious proportions steps should be taken to form central authority for prevention of pollution with complete control over all river functions, and power to carry out research and to act in an advisory capacity for industry.—*W. P. R.*

Pollution Control—By Whom? I. M. GLACE AND C. F. BROWNING. *Eng. News-Rec.* **122**: 380 (Mar. 16, '39). Protection against sewage discharges has been secured mainly through efficient treatment of water rather than by abatement of pollution. Since advent of water filtration and almost universal adoption of chlorination, treatment of sewage is not major health problem it was formerly and it has become problem in which other factors or agencies should be concerned. Notwithstanding this, administration of anti-pollution activities remains chiefly a responsibility of state health depts. Authors believe that this responsibility should be placed on agency where conservation, recreation and industrial interests as well as public health authorities are represented. Duty of reviewing and approving plans and projects should be duty of sanitary engs. of health depts. but they should not be required to say where, when and how much treatment is necessary. Several states have recognised this principle and have established sanitary water bds., conservation bds., etc. The other states should do likewise.—*R. E. Thompson.*

Pollution Control. C. W. KLASSEN. *Eng. News-Rec.* **122**: 542 (Apr. 27, '39). Discussion of article by GLACE AND BROWNING (See preceding abstract). Klassen agrees that pollution control should be administered by board composed of other than entirely health agencies. Results obtained by Illinois Sanitary Water Bd., created in '29 and composed of directors of public works and buildings, conservation, agriculture, health and fifth member representing industries, indicate that this is proper approach to pollution problem. Klassen, however, disagrees with inference that state sanitary engineers have allowed installation of "scores of so-called treatment works which scarcely merit the name."—*R. E. Thompson.*

Control of Pollution in Interstate Waters. ANON. *Am. City* **54**: 4:58 (Apr. '39). Departments of Health of N. Y., N. J., Penna., and Del. have ratified and made operative a reciprocal agreement to correct and control stream pollution within Del. R. Drainage Basin. Basin has been divided into 4 zones because of many variable factors and min. requirements concerning polluting matter have been established for each zone. Min. standards for each zone are given.—*Arthur P. Miller.*

The Flora and Fauna of Surface Waters Polluted by Acid Mine Drainage. JAMES B. LACKEY. U. S. Pub. Hlth. Repts. **53**: 1499 (Aug. 26, '38). Most highly acid-polluted waters support a few species of microorganisms occurring in large numbers and are distinctive indicators of this condition. Never elsewhere in such abundance (except *Oxytricha* sp. and *Pleuromonas jaculans*) have the ten most common species been found as in highly acid waters of investigated area. High tolerance for low pH values by *Pleuromonas jaculans* has been noted experimentally. Occasional findings of *Lepocinclis ovum*, and *Cinetochilum margaritaceum*, occurring in waters of pH 3.0 and 3.2 respectively, are not only significant of extended limits of pH range for these organisms, but also indicates that they may not be safely used as indicator organisms for this particular condition. Under extremely restrictive conditions of high acid concentration, there is an abundant group of microorganisms, which is potentially the first link in the food chain, ranging from these forms to minute crustaceans and insects and to fishes. While their numbers are frequently large, their environment is prohibitive to other forms and it should be emphasized that large numbers of other species do not appear until the pH nears neutrality (in these waters, 6.2 or above). This restriction of environment is strikingly illustrated by some of the Indiana pit lakes, clear, bluish-green bodies of water, without plants except cat-tails; showing no visible algae, few protozoa, no *Copepoda* or *Cladocera*, and devoid of fish life. It is entirely possible to determine the acid waters condition of these regions by biological surveys, involving relative abundance of limited number of easily recognizable species rather than knowledge of large variety of species.—*Ralph E. Noble.* (See also abstract following.)

Aquatic Life in Waters Polluted by Acid Mine Waste. JAMES B. LACKEY. U. S. Pub. Hlth. Repts. **54**: 18 (May 5, '39). Two coal mining regions, shaft mining areas in W. Va., and strip mining areas in Ind. and Ill., were visited and biological surveys twice made of their highly acid streams and strip pit lakes. A few adjacent almost neutral streams and lakes were surveyed for comparison. Total of 86 species of microscopic forms was recognized. Besides Thallophyta, Protozoa and Trochelminthes, only one of remaining phyla of plants and animals, the Arthropoda, was represented by more than one commonly occurring species in these acid waters. At or below pH 3.9, number of species found in any given habitat was very small. Largest number was 11 at pH 2.6 and several samples showed no life on examination. Practically the same forms were common in Apr. and Oct. but there was quite a difference in species termed "adventitious" which were found at the two different times. Seventeen species occurred in 15% or more of the samples and are termed "common." Most frequently occurring ones were as follows: *Euglena mutabilis*, *Naviculoid diatoms*, *Chlamydomonas* spp., *Distyla* sp., *Actinophrys sol.*, *Oxytricha* sp., *Ochromonas* sp., and *Ulothrix zonata*. Because most sharply definitive factor, sulfuric acid acidity, remains relatively constant, relative constancy of species occurrence indicates that this one factor outweighs all others. After strip pit lakes have been sealed to reduce acid production there appears to be little chance for them to become productive except by the initial development of a large flora and fauna of chlorophyll-bearing organisms. Inasmuch as 7 of the 17 organisms most common in this environment belong to this

category, this initial process is apparently already under way. Article includes 1 table, 6 figures and 4 references.—*Ralph E. Noble.* (See also preceding abstract.)

Pollution of Reservoirs by Gulls. BRITISH WATERWORKS ASSOCIATION QUESTIONNAIRE. *Wtr. and Wtr. Eng. (Br.)* 41: 564 (Dec. '39). A number of waterworks have experienced no large congregation of gulls on open storage reservoirs; 13 waterworks experiencing such large concentration of gulls have no reports on effect of these birds; 8 waterworks report such conditions as possible source of pollution. Expedients to overcome difficulty include firing of guns, stretching wires over reservoir at intervals of 4 to 8 ft., and rooting out nearby nests during the nesting season.—*H. E. Babbitt.*

Experimental Studies of Natural Purification in Polluted Waters. A collection of reprints of articles which appeared previously in U. S. Pub. Hlth. Repts. Published by the U. S. P. H. S. under the title given. ('39). In research studies of water pollution conducted by Public Health Service, principal objective has been to discover relationships between cause and effect—the conditions resulting from determinable contributions of polluting material to water courses and lakes, and methods by which such polluted waters return to their normal conditions through agencies of natural purification. These phenomena were first studied in several large rivers. Bacteriological, biochemical, chemical, and biological observations were correlated with engineering information on stream flow and liquid waste contributions. Results obtained and similar data from other investigations have provided quite definite knowledge of nature of polluted water and train of changes that may be expected to occur as result of contributed pollution. However, these biological and biochemical changes are affected by many factors which are difficult to evaluate in natural stream, therefore necessitating study of these complex reactions under conditions where variations in environment and physical and biological characteristics could be closely controlled. With regard to environment, variables were controlled by operating (1) at constant temperatures, (2) in a solution buffered sufficiently to prevent changes in hydrogen ion concentrations, and (3) with polluted water represented by simple medium which could be readily and exactly reproduced from day to day. With regard to control of biological variables involved, recourse was had (1) to use of pure cultures of bacteria, (2) to pure cultures of bacteria-free plankton, (3) to mixtures consisting of one species of bacteria with one species of plankton, and (4) to increasing complexities of inoculation until finally mixtures presumably contained gross flora and fauna of natural polluted water. By this procedure it was possible to obtain definite information regarding factors concerned in oxidation of putrescible material in polluted water, also of observed changes in numbers of bacteria and plankton present, and to evaluate separately the apparent functions of bacteria and of plankton in the process of natural purification. Simple technique for accurate determination of oxygen in small volumes of air was developed and the Winkler method for determination of dissolved oxygen was modified to provide for the estimation of dissolved oxygen in liquids containing large amounts of organic material.

Results are also presented concerning suitable dilution waters for use in biochemical oxygen demand determinations and in bacteriological examinations. The interference which may be expected in making dissolved oxygen determinations in the presence of organic matter, of hypochlorites, and of sulfites is indicated and methods are given for avoiding this interference. Data are also presented regarding the rate of oxygen utilization in sludge and on nitrification processes which may be expected in sewage mixtures. Results are given concerning nature and amounts of organic materials and of mineral salts required to stimulate the necessary biological activity and to provide for constant conditions. Mention is also made of apparent relation existing between food concentration in liquid media and resultant biological growths which may be expected. Comparison is made both on basis of number of organisms generated and on volume of living matter produced. Evidence is presented of part played by microscopic algae in reoxygenation of polluted waters which are being purified by natural processes. In tests designed to evaluate functions of bacteria and of plankton in oxidation by natural processes results obtained indicate that bacteria are active oxidizing agents while plankton, under natural conditions, contribute materially to this process in two ways: (1) By keeping bacterial population reduced below saturation point by their feeding on the bacteria, thereby stimulating continuous bacterial multiplication and maintaining resultant continuous oxidation to completion; and (2) by aiding in reoxygenation of polluted waters. Data are supported by numerous diagrams, charts, tables and references. The papers comprising this collection, references to their original appearance in U. S. Pub. Hlth. Repts., and references to their previous individual abstracts in this journal, follow:

1. THERIAULT, EMERY J., AND BUTTERFIELD, C. T. Apparatus and Technique for the Study of Biochemical and Other Oxidations in Liquids. **44**: 2256 (Sep. 20, '39); abst. J. A. W. W. A. **22**: 426 (Mar. '30).
2. BUTTERFIELD, C. T. Development of a Suitable Dilute Medium. **44**: 2647 (Nov. 1, '29); abst. J. A. W. W. A. **22**: 427 (Mar. '30).
3. BUTTERFIELD, C. T. A Note on the Relation Between Food Concentration in Liquid Media and Bacterial Growth. **44**: 2865 (Nov. 22, '29); abst. J. A. W. W. A. **22**: 569 (Apr. '30).
4. BUTTERFIELD, C. T., PURDY, W. C., AND THERIAULT, E. J. The Influence of the Plankton on the Biochemical Oxidation of Organic Matter. **46**: 393 (Feb. 20, '31); abst. J. A. W. W. A. **23**: 1096 (Jul. '31).
5. THERIAULT, EMERY J., McNAMEE, PAUL D., AND BUTTERFIELD, CHESTER T. The Selection of Dilution Waters for Use in Oxygen Demand Tests. **46**: 1084 (May 8, '31); abst. J. A. W. W. A. **23**: 1428 (Sep. '31).
6. THERIAULT, EMERY J., AND McNAMEE, PAUL D. Rate of Disappearance of Oxygen in Sludge of Grossly Polluted Water. **46**: 1301 (May 29, '31); abst. J. A. W. W. A. **23**: 1429 (Sep. '31).
7. BUTTERFIELD, C. T. The Selection of a Dilution Water for Bacteriological Examinations. **48**: 681 (Jun. 16, '33); abst. J. A. W. W. A. **26**: 419 (Mar. '34).
8. THERIAULT, EMERY J., AND McNAMEE, PAUL D. Dissolved Oxygen in

- the Presence of Organic Matter, Hypochlorites, and Sulfite Wastes. **48**: 1363 (Nov. 10, '33); abst. J. A. W. W. A. **27**: 140 (Jan. '35).
9. THERIAULT, EMERY J., AND MCNAMEE, PAUL D. Nitrification in Sewage Mixtures. **49**: 1169 (Oct. 5, '34); no abst. J. A. W. W. A.
10. PURDY, W. C. Reoxygenation of Polluted Waters by Microscopic Algae. **52**: 945 (Jul. 16, '37); abst. J. A. W. W. A. **29**: 1829 (Nov. '37).

—*Ralph E. Noble.*

Storage Lake Aids Stream Purification. G. M. RIDENOUR. Eng. News-Rec. **123**: 355 (Sep. 14, '39). Since '32, abandoned mill pond has been used for supplementary treatment of trickling filter effluent from Greystone Park Hospital, N. J. Pond is 15' deep at toe of dam and has surface area of 225,000 sq. ft. and estd. capac. of 2,000,000 cu.ft. Flow through pond averages 8.3 c.f.s., including 1.46 c.f.s. of sewage effluent. B.O.D. of latter varies from 25 to 40 p.p.m. and suspended solids average 32 p.p.m. Reduction in B.O.D. through reservoir averages 66.5% in summer and 52.5% in winter and reduction of coliform organisms 76 and 40%, respectively. O supplied by atm. absorption and photosynthesis, on basis of surface area, averages 10.1 grams per sq.m. per day in summer and 8.8 in winter. During one period of excessive drought, dissolved O dropped as low as 0.5 p.p.m. without causing odors. Graph is included showing relative calcd. O satn. values downstream with and without natural storage.—*R. E. Thompson.*

A New Process for Treating Waste from Steel-Pickling Plants. M. J. RENTSCHLER. Iron Steel Engr. **16**: 1:52 ('39). Base material, named "Ferron," possessing unusual structural strength, excellent heat-insulating qualities and resistance to high temps., has been produced from pickle liquor of steel plants. Ferron is easily drilled, sawed and machined; it is noncorrosive, and can be painted, shellacked and cemented. Small amt. of fiber, in form of ground-up newsprint or other waste matter, is added to pickle liquor and whole mixed in tank with slaked lime. Soln. is then diluted so that FeSO_4 is approx. 5% and acid about 2% and $\text{Ca}(\text{OH})_2$ added, with agitation, until acid is neutralized. Material is then pumped to pressure filter and ppt. transferred to pug mill, whence it emerges in continuous solid block. This is cut and placed in drier, where moisture is removed and material oxidizes and sets. Filtrate shows complete removal of Fe and silica and all heavy metals: it has high pH value, no bacterial content or O-absorbing capacity and is quite sanitary.—*C. A.*